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## THE GEODETIC SURVEY OF CANADA

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This subject is one which has not been much talked of in Canada except by those who have promoted it so that it likely will be new to the most of my hearers. The subject is such a broad one that many details must here be left out. This may, however, add something to the interest of the paper.

Goedesy is a science which treats of the figure and size of the earth. It naturally follows then that a geodetic survey is one which takes into account the fact that the earth is not a plane but a spheroid.

The need of such a survey has long been felt by this country. The absence of accurate maps has caused the expenditure of thousands of dollars on surveys which would never have been needed had a geodetic survey, and that which naturally follows, a topographical survey been made. A primary triangulation establishes the geographic position of points as far apart as topographical and atmospheric conditions will permit. Secondary and tertiary triangulations fill in important details and the topographical map shows the position of contour lines, rivers, roads, township and all land lines.

Land surveys were commenced in Canada towards the latter end of the eighteenth century and at first consisted of the measuring of tiers of lots along the principal rivers and the shores of the great lakes. As applications for additional surveys were made by incoming settlers township boundaries were surveyed in the localities desired. The subdivisions of these townships into concessions, or ranges, or lots were in some cases the work of three or four different surveyors. Errors rapidly accumulated and as the magnetic needle governed the courses of the lines and the measuring was exceedingly inaccurate the distortion of the townships was very great. The instructions given invariably directed the surveyors to lay out lots of uniform width and the maps returned showed the work as having been carried out according to the instructions. As a matter of fact in some townships in the vicinity of Ottawa, errors

amounting to hundreds of feet exist, and in one case a tract of land containing nearly a thousand acres was omitted altogether and the title remained in the Crown until a comparatively recent date.

These remarks apply to the whole of the older or more thickly populated portions of the Dominion and the township maps described have been used for the purpose of compiling the larger maps and are the sole official data available.

I give an extract from the report of the geographer to the Department of the Interior for 1902. Mr. White, alluding to the difficulties of compiling a map of Canada on a scale of 35 miles to the inch, wrote: "The lack of an accurate topographical survey, the numerous sources from which information must be obtained, the difficulty in many cases of obtaining access to the plans of old and almost forgotten surveys, the necessity of incorporating surveys that are being made concurrently with the compilation of the map, which frequently alter the work almost as soon as completed, all tend to make the compilation of such a map a long and tedious operation." Further on in the same report he wrote: "The difficulties in compiling the new map of Canada emphasize the need of a good topographical survey of at least the well settled portions of the Dominion. A few years ago I made a survey between two well defined points on Georgian Bay and the west end of Lake Ontario, respectively, which showed that part of Central Ontario, as shown by the best existing maps, was over two miles out in longitude and over a mile in error in latitude. Although our maps show streams, lakes, etc., even in the extreme north, much of the information upon which they are based is of the vaguest kind."

The advantages of an accurate topographical survey of our country might be set forth as follows:—

(1) Educational.—(a) By promoting an exact knowledge of the country; (b) by serving teachers and pupils in geographical studies.

(2) Practical.—As preliminary maps for planning engineering projects. Highways, electric roads, railroads, aqueducts and sewage plants may be laid out on them and the cost of preliminary surveys may be saved. Areas of catchment for water supply, sites for reservoires, and routes of canals may be ascertained from these maps.

(3) Political.—In all questions relating to political or legislative matters. For these purposes they afford accurate information as to the relations of boundaries and towns to natural features.

(4) Administrative and Military.—In all questions relating to Federal or State administration of public works, as canals, reservations, parks, highways and postal service, and as military base maps on which to place works of offence, defence, camps, marches, etc.

(5) Statistical.—As base maps for the graphic representa-

tion of all facts relating to population, industries, products or other statistical information.

(6) ECONOMIC.—As a means for showing the location, extent and accessibility of lands, waters, forests and valuable minerals. In this respect these maps are indispensable to State and Federal bureaus and to owners, investors and corporations.

(7) SCIENTIFIC.—The triangulation provides the data for the measurement of arcs of meridians or parallels of latitude.

The first step in a trigonometric survey is a thorough reconnaissance of the country for the selection of the most suitable points for the proposed system of triangles. No department of professional labor calls for the exercise of a higher order of ability, or better, repays thorough execution.

Certain general principles must of necessity govern this work, which is one requiring the exercise of skill and good judgment.

(1) Primary triangulation should be carried on with the fewest number of stations which the configuration of the country will allow. The best precision is obtainable by a system of quadrilaterals with every point intervisible; and next by a stem of hexagons where each exterior point sees a central interior station but does not necessarily see every other exterior point.

(2) Primary stations should occupy the crests of ridges or the highest accessible summits of mountain ranges.

(3) While the greatest care should be taken to obtain only well conditioned triangles, yet the only case where the rule of nothing less than 30° for an angle of a triangle should be rigidly adhered to is the case of a single chain of triangles admitting of no check between measured bases.

(4) An essential point in reconnaissance is the determination beyond possibility of a doubt of the intervisability of every primary line essential to the scheme.

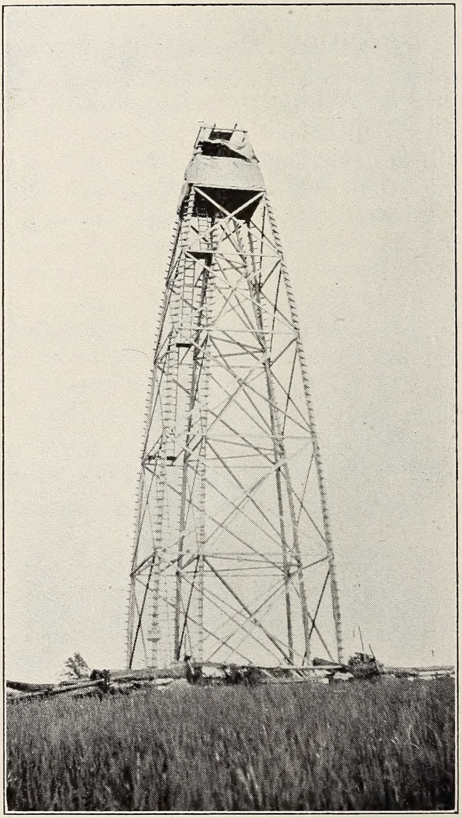
(5) Permanence of position for primary points, especially near the sea coast, is an object to be carefully looked to.

For a level country intervisability depends much on the distance apart and height of the observing towers. Refraction and curvature is here the factor to be taken into account and the general formula derived in the second applies. It is: Curvature and refraction$=(1\text{-}2m)\ \frac{K^2}{2R}$ where R is the mean radius of the earth; K is distance and m is coeff. or refraction. A shorter form of this is $.574 \times K^2$.

Our operations in Canada have been confined to the district between the Ottawa and St. Lawrence rivers as far as Montreal, and thence easterly across the southern portion of the Province of Quebec to the boundary of New Hampshire, also a triangulation with six angular points connecting two points on Lake Erie with the northern shore of Lake Ontario and including a point in Uxbridge township. The district between a point thirty miles west of Ottawa to Alexandria, about fifty miles to the east, has been found to present many obstacles to triangulation. There is a suc-

cession of ridges and depressions lying in an easterly and westerly direction. The ridges are, as a rule, timbered, or at least scattered trees occur, and there are few summits worthy of the name. The quadrilaterals covering the Ottawa district have sides from ten to thirty miles long, and when the angular points were occupied the observer ''cut in'' all church spires and subsidiary stations where such were necessary. From Alexandria easterly the country is more suitable for triangulation as it is in the main fairly level with occasional very prominent elevations. No observing was done in the Eastern Provinces in the summer of 1907. The triangulation in the west here, which is isolated from the eastern work, covers a comparatively large area of our country, one of the sides of the triangles being 56 miles long, while other lines are longer. The points are: Grand River, near Dunville; Font Hill, near St. Catharines; Binbrook about 15 miles south of Hamilton; a point in Nelson township; Scarborough; and a point in the southern part of Uxbridge township. The first two points are points used by the U.S. Lake Survey.

At the angular points of the quadrilateralts towers are built to make the points intervisible. These towers in Canada are built of wood and the form of construction is essentially the same as the illustration on page 181 of Colonel Clark's work on Geodesy. A footnote on page 180 states that the one illustrated was built by Sergeant Beaton of the Royal Engineers. Although built with the least material consistent with the required rigidity an 80-foot tower contains about 4,600 feet of lumber. They consist of an inner scaffold with three legs, for convenience called the tripod, on which the instrument is placed, and an outer scaffold with four legs on which lights are posted and on which the observer stands. In the erection of the towers one of the legs of



the tripod is raised first to be used as a gin-pole to raise the other two legs which have been framed together on the ground. Ties and diagonals are then put on and the tripod is used to raise the two opposite sides of the outer scaffold, which are also framed before being raised. A tower is built in about five days. The extreme rigidity of our towers, as evidenced by the accuracy of the results, will be dealt with later. This is, no doubt, largely due to the manner in which the towers are constructed. The curvature introduced into the upright members is so great that their construction necessitates the use of a block and tackle to draw the posts together in order to spike the ties and diagonals. A tent is made to fit around the top of the tower to protect the instrument from the weather.

Beneath these towers permanent marks are placed. They consist of an underground and a surface mark made of 2ft. tile set in and filled with concrete, the point of a 3-16″ copper bolt set in the concrete marking the exact spot. The top of the underground mark is placed about 4 feet below the surface and the top of the surface mark about 1½ feet below the surface so as to be below ploughing. Six inches of dry sand intervenes. A reference monument made of concrete is placed near each tower in a convenient fence corner or other out-of-the ?way place. Accurate linear measurements are made to it from the centre of th tower and the angle between the line to one of the towers and the centre of the monument is obtained.

The instrument used the past summer was a 12″ Altazimuth, made by Troughton and Simms. This excellent instrument was intended and has been used in the past for astronomical observations, and has been used in the past for astronomical observations, being provided with a 12″ vertical circle reading by two micrometer microscopes to single seconds. The horizontal circle also reads by two micrometer miscroscopes to single seconds. The only inconveniences about this instrument was its great weight which was a serious factor in getting it to the top of the towers in which work a block and tackle were employed. Lighter instruments have been ordered with three equidistant micrometer miscroscopes and without the large vertical circle. The focal length of the object glass of these new instruments is about 29 inches. It should be noted here, however, that it is questionable if the new instruments will be any improvement on our own, as the extra weight introduced into the English instruments has compensating advantages. Their extreme rigidity and slowness to answer to temperature changes are strongly in their favor for precise geodetic work, while the superiority of graduation of the circle makes up for the fewer number of microscopes.

Lately in the U. S. C. and G. S. triangulations the observer has made all the pointings for horizontal angles by using two parallel vertical lines in the diaphragm of the telescope, placed so as to subtend a horizontal angle of about 20 seconds. The centre of the

image pointed upon is placed as nearly as possible midway between the two lines. It is claimed that when all conditions as to brightness are favorable to accurate pointings the same accuracy is obtainable with the parallel lines as with the oblique cross the difficulty of bisecting accurately by eye a space of nearly 20″ being more apparent than real; that in making pointings at night upon an extremely faint image of a light the very faint illumination necessary to make the lines visible will cause the image of a light to disappear when an attempt is made to place the image pointed on very near the intersection of the oblique cross, but the illumination of the parallel lines under the same conditions will produce little effect upon the faint image nearly 10″ away and thus better pointings will be secured. The new instruments spoken of before will have this feature.

The method of observing the horizontal angles is the direction method. Each series of observations consists of successive pointings on the various stations in order from left to right with corresponding readings on the horizontal circle, followed immediately by pointings on the same stations in the reverse order after turning the instrument through 180° and transitting the telescope. The taking of reverse readings cuts out the effect of any error in collimation while the programme of pointings counteracts the effect of any twist in the tripod.

In making the measurements we measure each direction in the primary scheme sixteen times, a direct and reverse reading being considered one measurement, and sixteen positions of the circle are used. These positions are so selected that no microscope ever returns to the same part of the circle which it occupied before. When the observations in sixteen positions have been completed, the circle has been read at thirty-two points scattered over the whole circle at intervals which are about 11°. This insures that the mean value of each angle is almost completely freed from the effect of periodic errors of graduation.

In order to see from one tower to another heliotropes for daytime and acetelyne lamps for night observations are provided. The heliotrope is an instrument for reflecting the sun's rays in any desired direction. At night, when most of the observing is done, one account of the more equal atmospheric conditions, acetelyne lamps are used. The advantages of this light over the oil lamp with a condensing lens in the front are great. Oil lamps usually burn brighter after they have become heated and they are affected more by wind. Also it has been noticed that while the image in the telescope from an oil lamp gradually disappears under difficult conditions as on long lines or on account of haze, by becoming a diffused blur, under the same conditions the light from the acetelyne light becomes a small point of light which finally becomes too small and faint to be observed. Another point in favor of the acetelyne light is its distinctive color.

Two forms of acetelyne lamps have been tried by the Cana-

dian authorities. The one is a modification of the ordinary bicycle lamp. For the front door is substituted an optically good pair of 5″ condensing lenses with a stand to keep the carbide chamber off the lamp stand. This form the writer has found good on lines up to twenty-five miles in length. The other type is the ordinary automobile searchlight with a 6″ or 8″ convex lens and mirror at the back. This has a separate generator and gives a much stronger light than the one previously mentioned.

It was noted above that most of the observing was done at night, when more equal atmospheric conditions prevail. A short note on the difficulties to be met with in daylight observing might prove beneficial. In the section in the vicinity of Ottawa many of the lines pass in some places close to the tops of forests from which refraction is exceedingly irregular in volume and direction. Eccentricities in the closures of triangles have been noticed in the United States which are an indication of the occasional existence of atmospheric conditions fatal to accuracy.

That every precaution is being taken by the Canadian officials to avoid errors due to horizontal displacement of the image under observation is shown by the following extract from the instructions to observers: "Before attempting day pointing you will please spend at least ten minutes observing with the greatest care the action of the beam of light from a heliotrope, preferably the most distant or the one on the line at right angles to the direction of the wind. Your instrument should be in position on the tripod at least an hour before you make any pointings and the rays of the sun must not be allowed to reach that part of the tripod above the floor. Point your telescope so that the visible image of the beam from the heliotrope is as nearly in the centre of the space between the vertical wires as possible. If you find the vibrations of the image rapid, uncertain but symmetrical in magnitude and covering a small area, careful, deliberate bisections of this area may be made with confidence; but if you observe the image move slowly to one side and return with similar deliberation, even though this movement appears to be methodical, your pointings will be of no value for primary work."

Another point in daylight observing of primary angles may be noticed from the instructions: "Daylight readings of microscopes shall be made with the aid of artificial illumination. 'Every-ready' lamps are preferable and they should be held parallel to the graduation that the light may be thrown lengthwise of the grooves and light up their edges equally."

In a single line of quadrilaterals five signalmen are needed, while in double rows eight are necessary for occupying the central stations.

The duties of the signalman are to post his heliotrope or light and keep it burning and be ready at any time to receive signals for instructions. He is provided with a map showing the positions of the different towers, and a telescope. By placing the map on the

lamp stand and orienting it by the meridian he can generally find one of the towers. Then orienting it more exactly by means of the tower found he can point his light sufficiently closely to be seen by the observer who shows him his light whereby he is enabled to make the pointing exactly. The day's work for the signalman begins at 2.30 p.m., when there is sun, and continues till about twenty minutes before sunset, when the lamps are lighted. He goes on his tower about every twenty minutes from then till 9.30 to see that his lamp is burning properly and from that time till 11.30 he stays on the tower and keeps a sharp lookout for signals.

The Morse telegraph code (modified) is used to exchange signals, the dashes and dots being represented by long and short flashes of light, a cover being kept over the light between flashes. Certain code messages are used for messages which are frequently sent by the observer, such as:

*T H D*—I am finished with you for this half day.

*D G*—followed by name of station—Done, go to station named.

*S T*—followed by name of station—Show to station named.

This method of giving instructions saves an incalculable amount of time and also of money as the mails are slow and telephoning expensive.

Reference has been made to the rigidity of the towers as evidenced by the accuracy of the results. The instructions given for the summer of 1907 required that the means of the four groups of four positions each should agree within two seconds of arc and that the closing error of the primary triangles should not exceed one second. The spherical excess may be computed approximately by the formula: Sph. excess = 1″ of arc for each 75 sq. mi. of area. That such results were obtainable even in a wind with a velocity of fifteen to twenty miles an hour is sufficient proof of the rigidity of the towers. In this connection it may be said that United States C. & G. S. instructions require the closing errror to be within three seconds.

Just here a short discussion of linear measurements suggests itself. A paper on a Geodetic Survey would be incomplete were this subject ignored. From the inception of goedetic surveys the measuring of base lines has probably received more attention than any other part of the work. Extreme accuracy in this respect has until quite recently been considered of primary importance, it being considered better practice to introduce base lines measured with less accuracy at shorter intervals. The refinements of least squares computations are mainly responsible for the conclusion that the errors in the triangles composing the base nets between the comparatively short base lines and the longer sides of the quadrilaterals are largely in excess of any other class of errors, and all angular measures are of inferior accuracy when compared with linear measures. Hence it is considered better practice to select the ground for the base lines after the observing towers have been built so that the expansion may be as direct and perfect

as possible. In carrying on later work in the United States the practice of introducing base lines at comparatively short intervals has been followed and in their latest work the mean distance has been one hundred and seventeen miles.

Previous to 1906 base lines have been measured with tape lines which were referred to a comparator one hundred meters long, the length of the latter being determined by the iced-bar apparatus. This system has been used for many years but its efficiency has been materially increased by the use of Invar tapes. Invar is an alloy of 64 parts steel and 36 parts nickel, or thereabouts, and tape lines of this material may now be obtained in London. The temperature coefficient is smaller than that of any other known substance and tape lines of this metal are guaranteed not to contract or expand more than 1/1,250,000 part of their length for each degree centigrade or about 1 inch in 20 miles. Steel tapes require a correction of about fifteen inches in twenty miles for each degree centigrade. With regard to Invar the above figures are the maximum. The average results of tests of that metal show a coefficient of about 1/4 of the above or one inch in eighty miles. The accurate determination of the temperature throughout of any measuring apparatus has always been considered a most difficult problem. Scientific experiments have accomplished much in this direction but Invar has practically removed the necessity for further inventions or experiments in connection with measuring apparatus. Heretofore all tape line measurements of base lines have been made at night for obvious reasons. Field experiments and comparisons have shown that Invar tapes may be used in the daytime with absolute confidence and when properly standardized may be employed without the comparator, thus doing away with the iced-bar apparatus in the field.

A base line about seven miles in length near Coteau Jc., P. Q., has been selected but not measured with accuracy. The directness and perfection of the expansion from the extremities of this base to the sides of the main triangulation show the advantage of selecting the ground for base lines after the triangulation points have been occupied and brings great credit to the judgment of the official in charge.

The fact that Canada is only commencing work that has been in active progress in other countries for more than a century is not a subject for congratulation. There are, however, many palliating circumstances and in some respects we gain materially as we have the enormous advantage of the experience of other countries. We have also the benefit of comparatively recent inventions which aids to accuracy.

Now that we are making a primary triangulation which is the only scientific method of connecting detached surveys we may reasonably expect that other much needed surveys will follow until Canada will have maps of the country of which she may be justly proud. The progress of the work during the season of 1907

was very satisfactory considering the delays and the size of the staff.

In preparing this paper I have had recourse at several points to a paper given before the Ottawa Section of the Royal Astronomical Society by Mr. C. A. Bigger, the official in charge of the Geodetic Survey of Canada.

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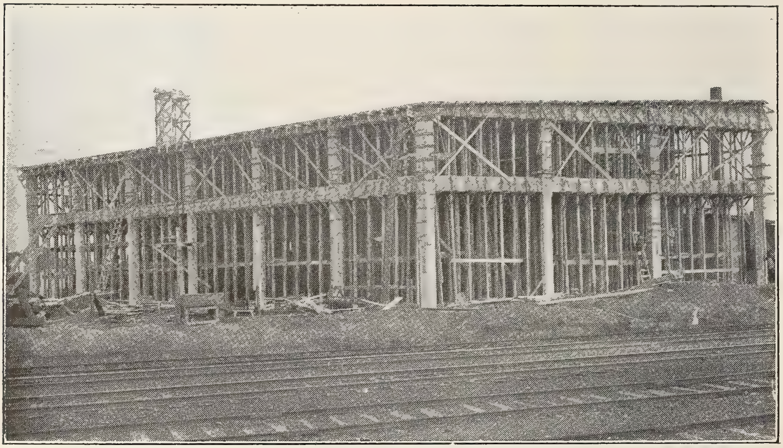
## COST OF A REINFORCED CONCRETE FACTORY BUILDING

D. L. C. RAYMOND, B.A.Sc., '04.

The importance of keeping accurate cost data in reinforced concrete construction is frequently underestimated by the contractor. In order to tender intelligently on similar work the recording of costs of labor in erecting forms, mixing and placing concrete, is especially important.

Fig. 1 shows a reinforced concrete factory building recently



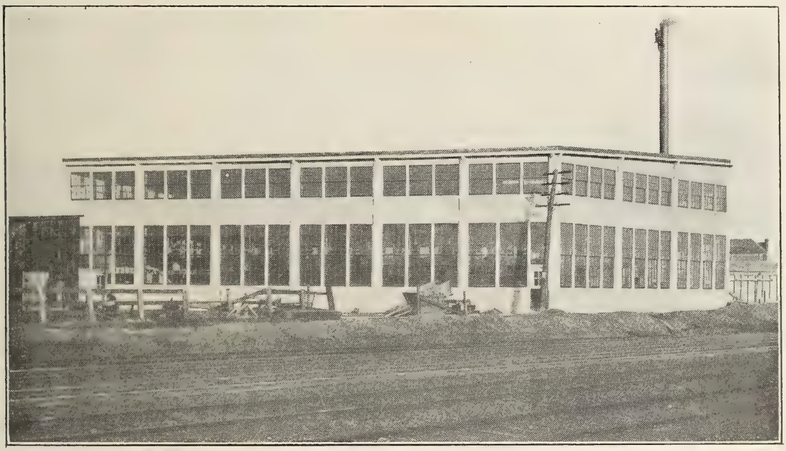
McGreggor, Banwell Fence Co., Walkerville, Building under Construction

erected at Walkerville, Ont. It is 100 x 100 feet two-storey building, with a gore extending 55 feet along one side. The ceiling heights are: First floor, 18 feet; second floor, 12 feet. The building was designed in skeleton construction, the windows extending from column to column, insuring a well lighted interior. The curtain walls, which were made 6 inches thick, were capped with concrete sills. The typical floor panel, 16 x 16 feet, has two intermediate beams. Kahn Cup Bars were used to reinforce the footings,

columns and beams, the floor slab being reinforced with Ideal wire reinforcement.

The mixing and hoisting equipment consisted of a No. 1 Smith batch mixer, capacity 10 cubic yards per hour; one boiler, which provided sufficient power for both hoisting and running engines, and a Ransome bucket in which the concrete was elevated to upper floor and roof. A hopper with a cut off into which the bucket dumped automatically prevented any delay while concrete was being poured.

The column and beam centering consisted of 2 inch Norway pine, dressed four sides. Considerable labor and expense was done away with by using iron clamps for column and beam boxes. The beam centering was supported at intervals of two feet by 4 x 4 inch cedar posts, crossed braced, under which maple wedges were placed. The floor centering was built of 1 inch Norway pine, dressed one



McGreggor, Banwell Fence Co., Walkerville, Building Completed

side, laid on 2 x 4's, 18 inch centres, supported by strips on sides of beam boxes. To keep the carpenters continuously employed the column and beam boxes were prepared while the concrete footings were poured; these were afterwards erected and framed.

A mixture of one part cement, two parts clean sharp sand, and four parts gravel to pass a one inch ring was used for concrete. The one inch finish was laid with floor and consisted of one part cement to two parts sand.

The following figures are based on cost data kept during construction. It will be noticed that the cost of centering seems high, while the cost of reinforcement is very low. This is due to the short span construction necessitating two intermediate beams which accordingly increased the carpenter labor and amount of lumber

used. This was more than offset by the saving in reinforcing material.

The laborers were all new to this class of work. Operations commenced Sept. 3 and the building was ready for occupancy Dec. 1st.

In all 847 cubic yards of reinforced concrete were used in construction. The total cost being $16,829.03, or $19.88 per cubic yard. The cost was made up as follows:—

| MATERIALS. | TOTAL COST. | COST PER CU. YD. |
|---|---|---|
| Cement at $2.05 per bbl........... | $3,314 08 | $3 91 |
| Sand and gravel at $1.25 per cu. yd. | 1,053 85 | 1 25 |
| Reinforced at $55.00 per ton........ | 2,314 08 | 2 75 |
| Centering, 4x4 cedar at...$25 per M. | | |
| 2x4 N. pine... 27 per M. | | |
| 1 in. flooring.. 28 per M. | 4,943 70 | 13 |
| Nails, etc. ........................ | 106 84 | 13 |
| LABOR | | |
| Building runs, hoisting and mixing concrete .... ......... | 872 00 | 1 03 |
| Placing and tamping concrete...... | 562 00 | 66 |
| Placing reinforcement ............ | 221 00 | 26 |
| Stripping, centering and cleaning up | 379 93 | 45 |
| Carpenters building and setting forms | 2,009 55 | 2 38 |
| Superintendence .... ........... | 714 00 | 84 |
| Tools and depreciation in equipment | 338 00 | 40 |
| | $16,829 03 | $19 88 |

# REINFORCED CONCRETE

L. G. ROBINSON, E.E.

*Mr. Chairman and Members of the Engineering Society:*

It affords me great pleasure to meet you in this manner. Your committee on papers (let us call them the reception committee) have introduced us to each other and have provided a topic for conversation, viz:—Reinforced Concrete. The subject is an interesting one from an engineer's point of view, for, by the very nature of his business an engineer must be an economist of the highest type. It is his duty to find out all he can of the characteristics of the material available for his work and assign to them the degree of importance each has by reason of its particular characteristics, availability, cost, etc., and then use them in such manner as to bring about the greatest good.

The ideal engineer is therefore an economist who exercises a high degree of "common sense" in the use of the laws of nature for the benefit of mankind.

Now, concrete is a well recognized common material of construction. Its use dates back into a remote and indefinite period, when it simply meant to the engineer so much artificial stone or rigid material of unknown strength and physical properties. It was used principally in great bulk for the sake of filling space and giving a firm foundation for structures of great weight, and it is even so used today, being one of the most pliable and easily worked materials for the purpose. About one generation ago, however, the engineers of England, France and Germany found that it was necessary to tie this material together by means of anchor-rods. It was discovered that concrete was subject to irregularities in its construction which caused in it fine cracks, fissures and seams, and apparently there was no law which governed the formation of these faults. The first idea which appealed to them in this case was therefore to insert steel rods or iron bars wherever they expected that the concrete would be subjected to any other stress than direct compression. There, gentlemen, was the genesis of reinforced concrete.

About this time theorists, mathematicians and engineers at the head of their profession began to enquire into the nature of the stresses and strains existing in beams generally. It did not take many years of research to find out that the internal stresses were very highly complicated. One theory after another would be propounded only to find that the hypotheses and the equations derived from them did not fit the case. And so hundreds and hundreds of experiments were performed in order to find out, if possible, what law existed. Needless to say none was found, therefore, empirical formulæ were established, some of which are in general use even today.

By this time the use of iron and steel was quite common. Steel and iron have always been expensive for the reason that it was such good material that the demand has always kept pace with the supply. In order to economize in the use of this material, investigation went on a pace. The empirical formulæ were revised time after time and, finally reached the degree of refinement which exists today.

It was found, however, that even steel had limitations which made it to some extent undesirable in permanent structures. It had to be protected from rust, fire, electrolysis and various other things. In searching about for the means of protection it was found that concrete enclosing the iron would successfully prevent the occurrence of most of these things to a large degree. It occurred to a few engineers at that time that a composite structure made up of steel rods and concrete would serve the same purpose as an entire steel structure incased in concrete and be much more economical. This then was the beginning of the *modern* form of reinforced concrete. Structures built in this manner were of a necessity heavy and massive. No attempt was made to reinforce concrete for anything other than direct tension. The economy which was *expected* was not wholly realized. Efforts were then put forth by the investigators to reduce the weight and size of this type of structure. By frequent tests of sample beams made up in this manner it was found that concrete almost invariably failed from shear. To prevent this they resorted to the placing of small rods in a vertical position in the concrete in such manner as to take up the internal shear stresses. This was called, at *the time,* a complete success.

As competition, however, became sharper it was found to be necessary to *still further* reduce the cost of this kind of work. From this time to the present day the quality of Portland cement has been steadily improving. The tensil strength of neat cement at that time was considered *excellent* when it withstood 250 lbs. to the square inch. At the present time it is not uncommon for a briquette of one square inch cross section to be unbreakable in a 1,000 lb. testing machine.

Now, to my mind there is nothing which will stimulate effort as much as a partial success. Twenty years ago reinforced concrete was called successful by a *few.* Its possibilities gradually dawned upon the engineering public, and it seems that every structural engineer made a tremendous effort to secure the advantages to be gained from the use of such a promising building material. Even the governments of several countries carried on extensive investigations in order to adapt it to their uses. The French Government found that when the rods used for reinforcing concrete for shear stresses were made fast to the main tension reinforcement the strength of a beam could be thereby increased about 20 per cent. As soon as these reports were published, private investigations also were largely directed in that way. Whenever such investigation proved satisfactory to the individual, the form which the shear

members and tension members took, and their relation to each other was called a "system." At the present time *systems* have multiplied until, it is safe to say, there are at least twenty systems in common use. Now, here again exists a problem for our ideal engineer. Which system shall he use? Is it necessary for him to go over all the ground covered by the various investigations, both public and private? I think not. The reports of these various systems and of the work carried on at the government's expense furnishes abundant information upon which he can base his opinions. Let him first go back to the mathematician's analysis of the stresses in beams. Get these firmly fixed in mind so that when going over the multitude of suggestions and arguments for and against the different systems, he will not lose sight of *his own* conception of the nature of the stresses in a beam.

Let us try and see if we can get an idea of what this conception would be in the case of a simple rectangular bear supported at each end and subjected to a load.

The first idea which occurs to the analytical mind is that unless he beam is rigid it will bend or break under the load. Now, we all know that there is nothing in the world which is absolutely rigid. Our beam is, therefore bound to bend and in bending, the lower portion of the beam will be subjected to tension. On the other hand the upper portion of the beam will be subjected to compression. At some plane lying between these two conditions there is no stress whatever of tension or compression. This is called the natural plane or neutral axis.

The next idea which presents itself is that the upper portion being in compression and the lower in tension these two forces must be in opposition to each other in order to preserve equilibrum. Hence, there must be a tendency for the upper portion to slide upon the lower portion. This we call longitudinal shear. A good analogy would be to imagine two boards one laid upon the other flat upon supports at either end and a load placed upon the middle of them. They will bend, and it will be noticed that the upper board actually does slide upon the lower board in a longitudinal direction so as to extend beyond it at the ends.

Again, there is another tendency for each of the supports to push off a piece of the beam in a vertical direction. The combination of this force and the longitudinal shear, resolved into one by the parallelogram of forces, will result in a force which is neither perpendicular nor horizontal but inclined to these approximately 45 degrees. If the material in the beam is not strong enough to withstand this force it will part in a plane which is perpendicular to the direction of the resultant at each point of failure.

Now, whatever may be the conditions of loading these three actions take place in *every* beam, and their relative amounts are according to the conditions of loading. In order to prevent the failure of a concrete beam, the reinforcement must be so designed as to successfully sustain these stresses at all points. In most cases the conditions of loading vary. A structure may be partially

loaded, fully loaded, or the load may be concentrated at some point or points, or it may be uniformly distributed over all the structure.

The judgment of the designer here comes into play and it is *impossible* to eliminate at this point his *personal equation.* He will have to study the conditions which will be imposed upon the structure and so proportion the combining parts of the same in such a manner as to take care of the most severe conditions to be expected. Obviously, then, he must have a system of reinforcement at hand which is so flexible in its nature that he can readily dispose the steel throughout the concrete as to meet with his requirements without undue elaboration or expense.

*Economy* calls for the disposition of steel in such a manner that there will not be an *excess* at any point above what is required to resist tension and shear of the concrete. As to compression, the value of the resistant powers of concrete are very well known and it is an easy matter for one to provide ample proportions to meet with this requirement.

Steel in the form of rods or bars will satisfactorily sustain tension and its ability to do so is also well known. The question is not very difficult when only the tension in a beam is to be considered, but how to dispose the steel in such a manner that in *tension* it will successfully resist the *shear* stresses of the structure is the *crux* of the *whole matter.* Upon this point is determined the merit or de-merit of all the various systems for reinforcing concrete.

We are ready now to draw conclusions. In the light of the above analysis and discussion we are able to say what shall be the *principal characteristics* of a reinforcing system which shall be best adapted to construction:—

1. There must be a Main Tension Member.

The variation of the strength of this member must be easily accomplished.

The size and shape of this member should not be such as to make it difficult to thoroughly imbed it in concrete, for in order to allow it to develop its whole strength and efficiency in the structure it must be so intimately in contact with the concrete that it cannot slip longitudinally. Right here it may be said that numerous experiments have been recently performed for the purpose of finding out how much grip may be depended upon between the concrete and steel. It was found under various conditions that a good wet mixture of concrete would develop a surface cohesion amounting to from 210 lbs. to 450 lbs. per square inch superficial area of the steel. This feat depends so much upon the workmanship that it has been found best to impose a generous factor of safety. It is the custom to expect a working adhesion of 50 lbs. per square inch.

*The form of the steel* should be such as to make it quite easy to attach the shear members to them; this will be determined largely by the *method adopted* for the attachment.

2. There must be Shear Members.

They must be so placed that when acting in tension they will resist shear stresses.

They should be attached to the main tension members.

This attachment should be such that the shear members may be placed in position at any point along the beam and as frequently as desirable.

One should be able to incline them to any angle and make them of any length to suit the structure in which they are to be placed.

They should not be very heavy. On the other hand, they should be as light as it is possible to work them; for, the stresses which they are to take up are by nature *distributed* stresses, and, so the greater the *number* of them interspersed throughout the concrete the more perfectly will they take up the stresses as they exist in the beam.

3. From the standpoint of economy, availability, cost, etc., the steel of which this system is made up should be of such forms as are usually obtained in commerce, i.e., *commercial forms.*

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## TECHNICAL PHOTOGRAPHY

G. R. ANDERSON, M.A.

The statement has often been made that the nineteenth century witnessed a development of scientific knowledge and the application of science to art and industry surpassing the aggregate of all previous progress, and when the field is carefully surveyed few will doubt its truth.

Amongst the multitude of scientific discoveries that have made the past century so famous probably no single one can show a more brilliant record than photography, whether it be judged merely as a series of successful researches in the domain of chemistry and physics or by the range and importance of its applications.

Progress in the early days was somewhat slow and when we remember that the first crude plates of metal coated with asphaltum required ten hours exposure, it must be admitted that the outlook was not very promising. A few years later the secret of the daguerreotype was made public by means of which process a picture could be produced by an exposure of a few minutes. These processes, however, were both positive, the picture being in each case a finished product from which duplicates could not be made.

The introduction of the glass plate fifty years ago on which the negative is produced and from which an indefinite number of positive prints may be made was a revolution. True, the collodion wet plate was troublesome to work; it had to be exposed and developed before it had dried and so necessitated an outfit of chemicals that prevented its use except in connection with a dark room. The results obtained were, however, satisfactory, and the art of photography was assured of success.

The perfecting of the gelatine dry plate forms another landmark in progress by which the elaborate outfit of chemicals hitherto necessary was dispensed with and the photographer was able to take a stock of prepared plates to any place desired, make the required exposures, and complete the development on his return.

The closing years of the century saw important advances made in orthochromatic and color photograph, in the discovery of new printing processes, in the introduction of cinematography, or the photography of motion, and in the perfecting of the lens and mechanical equipments of the camera that make it a model of perfection among scientific instruments.

From the time of the first photographic discovery the problem of photomechanical printing has been constantly in the minds of experimenters. As early as 1842 an attempt was made to produce an electro plate from the daguerreotype, and in 1843 a process was patented for etching the same with acid. These attempts were not very successful, but some fifteen years later the Woodbury process of printing from a gelatine relief was perfected and in a modified form is still in use. A great variety of photo-engraving processes have followed so that results are now obtained in monochrome and color that it would seem hard to improve upon, showing that this phase of the work was quite kept pace with that of photography itself.

In the mind of the general public photography is associated mainly with two classes of operators: the "professional," who occupies a studio and whose work is confined almost entirely to portraiture, and the "amateur," with his kodak, who snaps anything and everything in sight. But while these two classes occupy a large share of attention by reason of their numerical strength, they by no means occupy a large portion of the field of usefulness open to the art. The work of photography for newspaper and magazine illustration alone is enormous, and if directed in a proper way becomes an educational factor of prime importance. In the realms of pure science photography has been of the utmost value in promoting scientific research, the eye even of the trained observer is prone to err and a multitude of details cannot be comprehended at once, but a photograph is a true record which can be examined at leisure and compared with the results of future experiments. The camera may be combined with the microscope and telescope, and the photographic plate made to record with equal facility the structure of the minutest organism or the constellations of the fixed stars.

To what use is photography put in the theory and practice of engineering? and what is the outlook for its increased application? It has been said that "drawing is the written language of the engineer," and may it not be added that "photography is his short-hand"? While it may not supersede drawing it may supplement it in many ways. In the laboratory tests of almost every

description may be most accurately and expeditiously recorded photographically, while drawings and diagrams may be duplicated for instruction or reference.

In the actual practice of engineering photography has been steadily on the increase for a number of years. In construction work it is now considered necessary to record the progress of the work in detail from start to finish, these prints form a record of progress for the offices so that the amount accomplished at any time may be ascertained, and when the work is finished the history of the construction from its inception to its completion is readily available, and forms most valuable information for future work. Such a record is practically impossible by any other method.

It is perhaps interesting to note that photographic surveying has been carried out on a far more extensive scale in Canada than anywhere else. The first work of this kind was done in connection with the route of the Canadian Pacific Railway through the Rocky Mountains, and in 1893 and 1894 the Canadian section of the International Boundary Commission carried out a photographic survey of about 14,000 square miles of territory along the boundary between Canada and Alaska. Since then very large areas in British Columbia have been surveyed by the same method. These surveys, on the authority of the Surveyor-General, can be executed at a fraction of the cost of other methods and with greater precision, so there seems to be no valid reason why the method should not be almost exclusively used where the nature of the country warrants it.

Many other applications of the camera might be enumerated and will no doubt suggest themselves to the reader, but enough has been said to show how wide and varied are the uses to which photography may be put and its great value as an aid to scientific work. Such being the case, it is, we think, of prime importance that every student and practical worker who desires to have such an aid should make himself master of the rudiments of the work.

I shall conclude this paper by giving two simple examples of the application of photography to numerical work which requires no special apparatus.

1. Given the position of any point to determine the distance of another point further away. Let two photographs be taken, including both points, from two stations a known distance apart, the camera having the same bearing in each case.

Let $P'$ be the known point at distance $A$.

Let $P$ be the required point at distance $D$.

Let $F$ be equal the focal length of the lens.

Let $X$ and $Y$ be the separation of the points in the resulting photographs.

Let $E$ equal the base line.

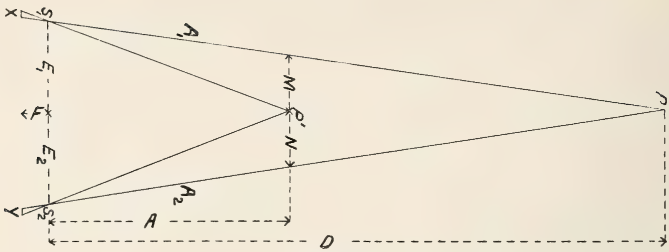


Fig. 1

$$\text{Then } \frac{Y}{N} = \frac{F}{A_2}, \quad \frac{X}{M} = \frac{F}{A_1}$$

$$\therefore \frac{X+Y}{M+N} = \frac{F}{A} \text{ approx.}$$

$$X + Y = \frac{F}{A}(M+N) \quad \ldots\ldots \quad (1)$$

$$\text{Again, } \frac{M}{E_1} = \frac{D-A}{D}, \quad \frac{N}{E_2} = \frac{D-A}{D}$$

$$\therefore \frac{M+N}{E} = \frac{D-A}{D} \quad \ldots\ldots \quad (2)$$

$$\text{From (1)} \quad \frac{X+Y}{E} = \frac{F}{A} \cdot \frac{M+N}{E}$$

$$\text{Subst. in (2)} \quad \frac{X+Y}{E} = \frac{F}{A} \cdot \frac{D-A}{D}$$

$$\text{Or} \quad X + Y = E \cdot \frac{F}{A} \cdot \frac{D-A}{D}$$

$$\therefore D = \frac{A \,.\, E \,.\, F}{EF - A(X+Y)}$$

The subjoined photographs, taken a couple of years, represent an application of this method to the determination of the distance of the Union Station from College Street, the base line in this case

Fig. 2

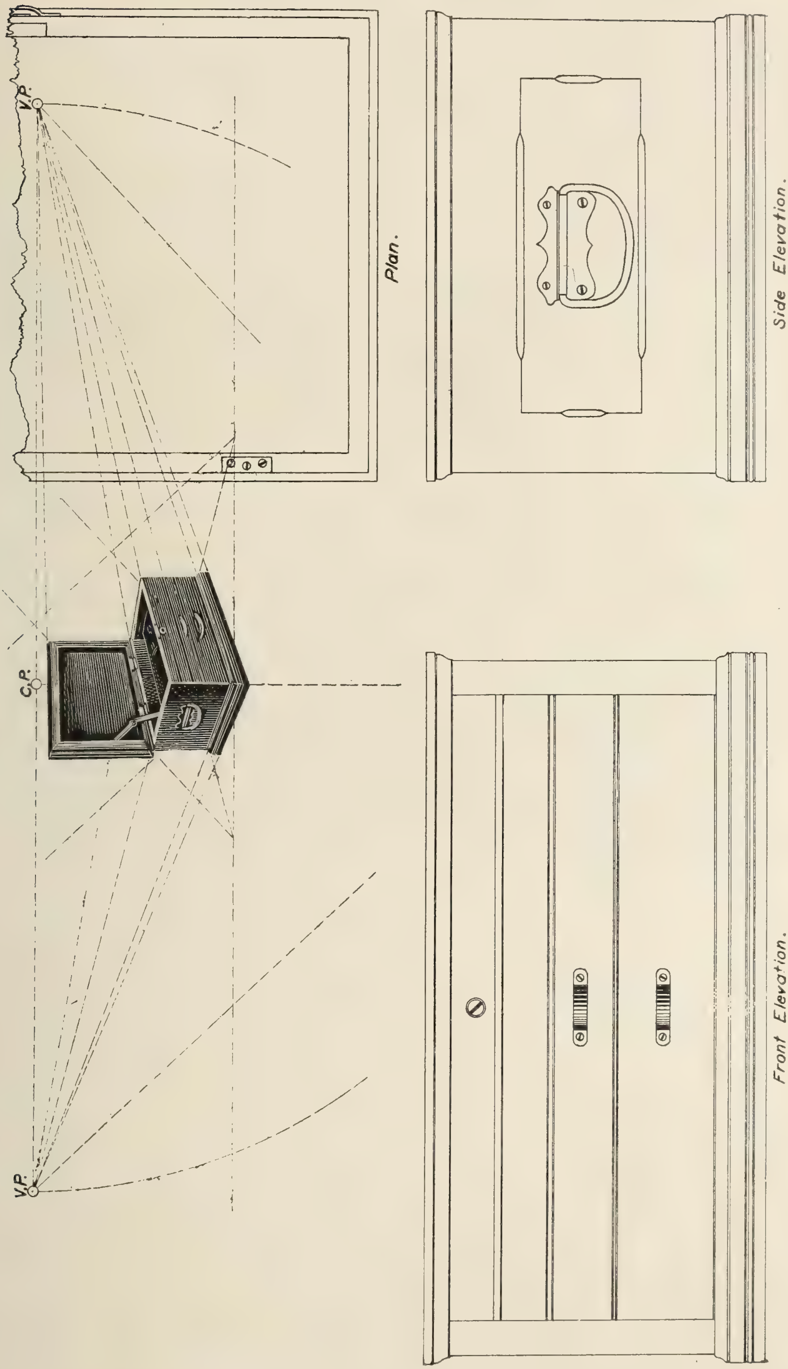


Fig. 3

being 116 feet, the distance A 1,600 feet, and the focal length of the lens 6 inches.

The result calculated from the prints was less than 5 per cent. in error, which may be considered a fair result.

### Problem 2.

Given the focal length of the lens and its distance from a vertical line of an object to produce a drawing to scale from the photograph.

Let $F$ equal focal length of lens.

Let $D$ equal distance from optical centre of lens to object.

Let $L$ equal length of any vertical line of object, and $l$ equal the length of this line in the photograph.

Let $x$ equal distance from lens to plate.

$$\frac{1}{D} + \frac{1}{x} = \frac{1}{F} \quad \text{whence } x \text{ is determined}$$

Then

$$\frac{l}{x} = \frac{L}{D} \quad \text{whence L is determined}$$

This gives the dimensions of one line of a perspective drawing and from this drawing the elevations of such faces as are visible may be constructed.

The accompanying illustration from a class problem shows the application of the method to the detail drawing of a small tool chest. In this case the error in the result was under 2 per cent., which amount would be decreased if more than one photograph were used.

The accompanying illustration from a class problem shows the application of the method to the detail drawing of a tool chest.

# A NEW TYPE OF CRUDE OIL ENGINE AND SOME INDICATOR DIAGRAMS

H. ADDISON JOHNSTON, '00.

The internal combustion engine has developed so rapidly during the past ten years that it is very seldom that small steam engines are met with in commercial operation, except as auxiliaries in large power plants where steam is always available.

The fuel generally used in small internal combustion engines is gasoline, but a small number use city gas, and a very few kerosene. All these fuels are manufactured products, and hence are very expensive. In small units the total cost of power is low because very little fuel is used, but when over 20 h.p. is required the cost of fuel becomes excessive. Moreover, the increased use of gasoline engines is causing such a demand for gasoline that the oil companies have difficulty in obtaining a sufficient supply as the percentage of gasoline in crude petroleum is very low. The price of gasoline has more than doubled in the last few years, and there is no indication that the top price has been reached yet.

The use of crude oil in internal combustion engines has seemed to the writer to be the solution of the cheap power problem, and after about four years of constant experimental work an engine has been developed which will operate perfectly on any grade of crude petroleum or its refined products. Crude petroleum varies in price from less than one cent to about five cents per gallon, according to locality, quality and transportation conditions. The engine developed by the writer will deliver 10 h.p.-hrs. on three-quarters of a gallon of any kind of oil, hence, even at the highest price, the cost of fuel amounts to less than one-half cent per h.p.-hr., and at the lowest, under one-tenth cent per h.p.-hr.

The principal cause of failure of previous attempts to use crude oil in internal combustion engines has been the clogging of the various parts of the mechanism with tar and carbonaceous material from the fuel. This trouble is due to the fact that experimenters have endeavored to vaporize the oil to form explosive mixtures. Crude oil contains a large percentage of heavy hydrocarbons which will not vaporize under the action of heat, but merely break up into lighter hydrocarbons and tar, the latter settling on the nearest support and building up until it interferes with the running of the engine.

It is thus quite evident that for a successful machine, some other method of operation must be devised. It is well known that both tar and carbon will burn under proper conditions, hence the problem is reduced to the providing of such conditions in an intenal combustion motor that the tar and carbon contained in the oil will be instantaneously consumed.

The most favorable conditions for the rapid combustion of

any fuel are these: the fuel should be broken up into the smallest possible particles; each particle should be surrounded with air; and the air should be at as high a temperature and pressure as practicable. If it is assumed that ten per cent. of the bulk of the oil will appear as tar under the action of heat, and that the largest particle of oil after breaking it up is one-two hundredth of an inch in diameter, then after the ninety per cent. of oil has burned off there will be left a particle of white hot carbon a little over one-thousandth of an inch in diameter, and surrounded by air at a very high temperature. Under these conditions the carbon burns instantaneously and no fouling of the cylinder walls or passages is possible. It has been assumed that the small particles of oil remain suspended in the air until they are burned. In practice it has been found that if a water-jacketed combustion chamber is used that some of the oil strikes the cold walls and sticks there, the lighter portion burns off and the tar remains, eventually causing clogging. If, however, the cylinder walls are kept at a temperature high enough to shed the oil as water is shed from a hot iron, then there is no tendency for tar to accumulate, and after a long run the cylinder will be found to be burned absolutely clean.

Fig. 1 shows the cylinder construction by which the conditions for rapid and complete combustion are provided.

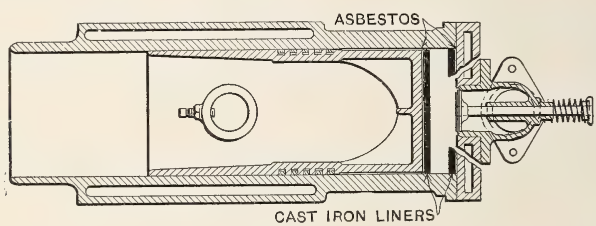


Fig 1

The cylinder and piston are each provided with an extension which is not cooled. The water jacket extends only over that part of the cylinder in which the piston rings run and the piston extension is made one-sixteenth inch smaller in diameter than the bore of the cylinder, and hence does not touch the cylinder walls. On the end of the piston and on the inside of the head there is an asbestos insulated liner which prevents the escape of heat from the combustion chamber.

In operation the cycle is as follows: Air alone is drawn into the cylinder through a mechanically operated inlet valve during the suction stroke; on the return stroke the air is compressed to about 150 pds. per square inch, and just as the crank reaches the centre a charge of crude oil is sprayed into the cylinder by compressed air and is immediately ignited by striking a hot plate on the end of the piston. The fuel burns practically instantaneously and the rise in temperature of the charge causes a corresponding rise in pressure. (At full load the maximum pressure may reach

400 pds. per square inch.) The piston is forced out by the expanding gases and at the end of the stroke the exhaust valve opens, allowing the burnt gas to escape during the succeeding stroke.

To ignite the first charge when the engine is cold a thimble is provided on one side of the cylinder which is heated red hot by a torch, this operation requiring about three minutes. When instantaneous starting is required an electric device is provided which fires the first few charges. After the engine is running no further heating is required as the combustion of the oil keeps the plate on the end of the piston at a temperature above the ignition point.

Compressed air for spraying the fuel and for starting the engines is supplied by a two stage air pump attached to the crank shaft.

In working out the principles of this engine many thousand indicator diagrams have been taken and a few interesting types are shown herewith.

The first two months after the experimental engine was finished were occupied in attempts to make the engine run, and continue to run, on fuel oil, and at the end of the second month we had progressed so far that the engine would continue running if no load were put on it. The M.E.P. of our indicator cards at that time did not average more than 12 or 15 pds. This low figure was gradually improved upon until after four months 45 pds. was reached.

About this time the "explosion wave" began to give evidence of its existence and Fig. II. shows the register of an explosion wave on the indicator card. It will be noticed that extremely violent vibrations were set up in the indicator piston and that the vibration continued almost the entire stroke. The suppression of these explosive waves constituted the most difficult problem in the working out of this type of engine, and it is most fortunate that the laws governing their formation have been discovered. The external evidence of these waves was a terrific pound, which would cause an observer unfamiliar with the case to think that the engine was knocking itself to pieces. In the gas engine pounding is caused only by too early ignition, but that the cause is not too early ignition in this case may be seen by examining Fig. III., in which case the igniation is quite distinctly too late, but the explosion wave is still there.

An average normal diagram is shown at Fig. IV., M.E.P. 95 pds. The highest M.E.P. yet obtained on a normal card is 107 pds. Fig. V. shows very clearly the action of the governor in cutting off the supply of fuel when the load is reduced. Note that the compression pressure remains the same in every case, giving ideal conditions for high efficiency under light load.

Fig. VI. shows two diagrams taken at different speeds. The increased inertia effect of the indicator drum at high speed stretches the indicator card and makes the diagram longer. Note that while no change has been made in the timing of the fuel valve

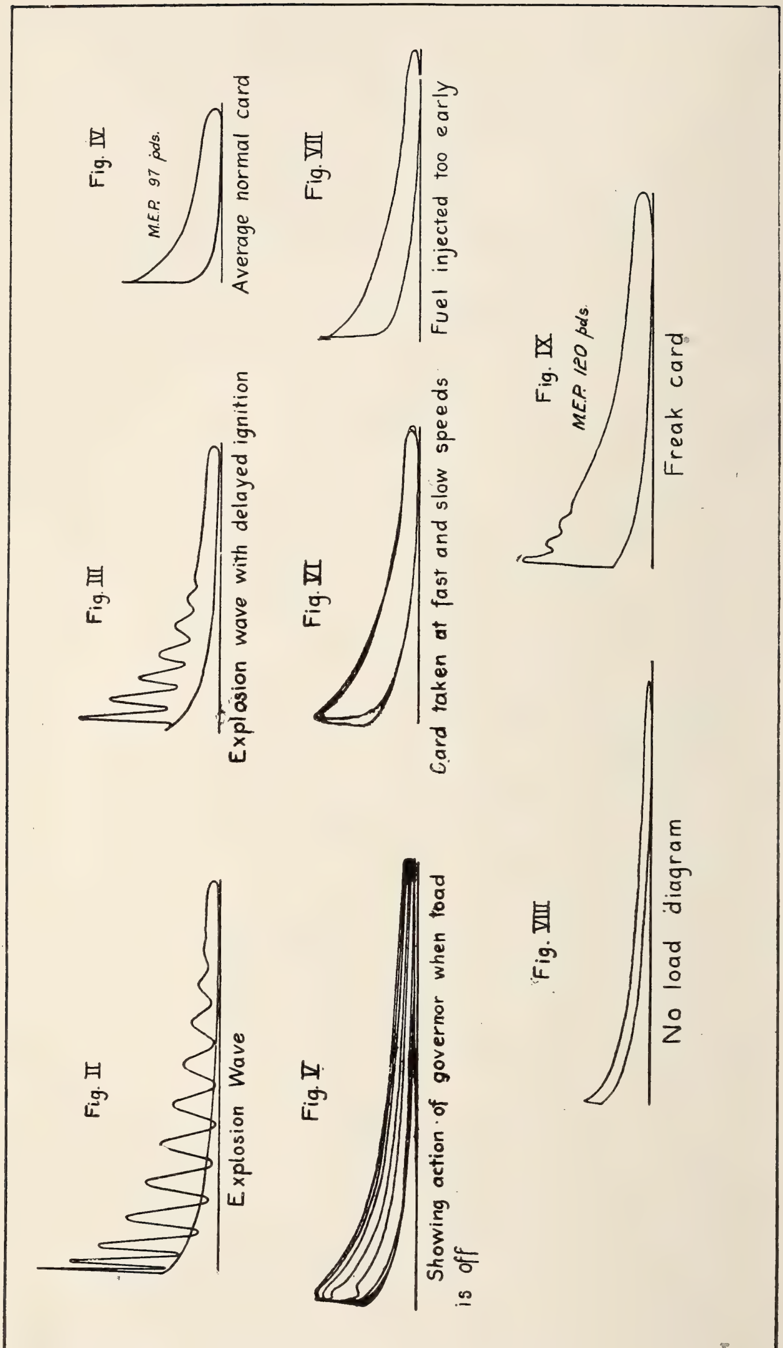
Fig. II
Explosion Wave
Fig. III
Explosion wave with delayed ignition
Fig. IV
M.E.P. 97 pds.
Average normal card
Fig. V
Showing action of governor when load is off
Fig. VI
Card taken at fast and slow speeds
Fig. VII
Fuel injected too early
Fig. VIII
No load diagram
Fig. IX
M.E.P. 120 pds.
Freak card

the ignition occurs approximately at the correct time at both speeds.

Fig. VII. shows the effect of injecting the fuel too early in the stroke. The maximum pressure is reached before the piston has completed the compression stroke.

A typical no load diagram is shown at Fig. VIII.

Fig. IX. is a freak. This card was obtained when the engine was being started. The previous charge had not fired, part of it remained in the cylinder, vaporized, and was fired with the succeeding charge just at the right minute.

The 60 h.p. two cylinder vertical engine shown in the cut* is built for direct connection to generator and runs at 300 r.p.m. Its guaranteed fuel consumption is 4½ gallons crude or fuel oil per hour, full load. It is equipped with compressed air starting mechanism, which turns compressed air into each cylinder alternately at the time corresponding to its power stroke. The small two-stage air compressor seen beside the cylinder is driven from the crank shaft and supplies air for starting and for spraying the fuel. The engine may be started at any time in less than five minutes, and when once started needs no further attention. The cranks run in oil and outside bearings are lubricated with ring oilers.

With oil at 4 cents per gallon, 100 h.p.-hrs. from this engine would cost only 30 cents, or $9.00 per horse-power-year on a ten-hour day basis.

*Note—See page ii, advertising section, for cut of 60 h.p. two-cylinder vertical engine described above.

# A COMPARISON OF DIRECT CURRENT AND INDUCTION MOTORS

L. G. IRELAND, '07.

It is the purpose of this article to make a brief comparison of the relative advantages and disadvantages of the polyphase induction motor and the direct current motor, more particularly the shunt motor, since its characteristics most nearly approach those of the induction motor.

The work which motors are called upon to perform may be broadly divided into two classes:

(1) Constant speed operation,

(2) Variable speed operation.

Let us first consider the case of constant speed operation. For constant speed work the squirrel cage type of induction motor is used. In this type the line connections are made to the primary or stationary element and the secondary or rotating element consists of a winding of copper bars permanently short-circuit by rings at each end. The secondary receives its currents by induction from the primary, the alternating currents in which set up a synchronously revolving. It is thus evident that no electrical connections are made to the revolving element, and in this elimination of moving contacts lies one of the greatest advantages of the induction motor. The secondary of an induction motor is also much more simple mechanically than the armature of a direct current motor with its commutator and all its attendant troubles.

Speed regulation is usually defined as the difference between no-load speed and full-load speed, expressed as a per cent. of no-load speed. This quantity, when used in connection with induction motors is termed full-load slip. The performance of the induction motor in regard to speed regulation is, in general, superior to that of the shunt motor. The following figures give values of speed regulation for both types of motors under constant voltage conditions:

Shunt motor - - - - - - - - - 10 to 12% drop.
Induction motor - - - - - - - - 3.5 to 5% slip.

The above figures are merely average values, considerable variation being found in different motors. Very few induction motors, however, have a full-load slip higher than 7%, unless specially designed with high-resistance short-circuiting rings in order to give a very large starting torque.

The induction motor requires no attention while running, whereas if the speed variation of the shunt motor is to be kept within the limits of the induction motor, changes must be made in the field resistance as the load changes, and it is possible, of course, to obtain perfectly constant speed by this means. This latter case

is scarcely worth considering, as the attendant would require to spend more time in manipulating a rheostat than in operating his machine.

*Variable Speed Operation.* For this class of service direct current motor is superior. The speed control of direct current motors is obtained by varying the resistance in either the field or armature circuit. The analagous methods for the induction motor are variation of the primary voltage by means of autotransformers, and the use of a phase-wound secondary with variable external resistance connected to slip rings. A third method has been slightly used, namely, that of varying the number of poles. It involves a complicated and costly construction, besides giving only a very limited number of speeds. We will therefore consider only the first two methods.

For a given load the efficiency of a shunt motor is approximately constant at all speeds obtained by field regulation. On the other hand, the efficiency of the induction motor decreases more rapidly as the speed is reduced by voltage regulation. When running at low speeds under variable load conditions, by armature and rotor resistance regulation respectively, both motors show a lack of stability in regard to speed.

A wide range of speeds can be obtained by field resistance variation in shunt motors while in induction motors the range of speeds is comparatively small, or in other words a much greater flexibility of speed control can be obtained from shunt motors than from induction motors.

*Starting.* The squirrel cage motor is started in a slightly more simple manner than the direct current motor. The former is started by applying by means of autotransformers a reduced voltage to the primary terminals and connecting directly to the line when the motor has attained nearly normal speed. If the motor has a wound secondary with starting resistance, the primary is first connected to the line, all the resistance being in series with the secondary, and the resistance is gradually cut out as the speed increases, until at normal speed the secondary is short-circuited. This method of starting possesses no advantage over the analagous method used in starting direct current motors as far as simplicity is concerned, but it has the very decided advantage of producing a very large starting torque. It is possible, if the secondary resistance is of proper value, to obtain, at starting, the maximim torque which the motor is capable of exerting. The effect of large starting torque may also be obtained in a lesser degree in squirrel cage motors by using high resistance short-circuiting rings but this involves a sacrifice of full-load efficiency and an increased full-load slip.

The method of starting by means of secondary resistance is preferable to starting by means of reduced voltage. When the latter method is used the motor consumes at starting a very large current of low power factor with resulting bad effect on the generator and line. The former method largely obviates these troubles.

*Efficiency.* The full-load efficiency of the direct current motor is equal to that of the induction motor in good modern machines. At light and medium loads, however, the efficiency of the induction motor is better than that of the direct current motor. It is clear that this is a very important consideration as very many motors run on light loads a large part of the time.

*Power Factor.* Induction motors never operate at 100% power factor, but always consume a lagging current. The power factor at full load is usually about 90% and is much lower at light loads. This is due to the large relative magnitude of the magnetizing current at light loads. The presence of wattless currents does not mean much loss of energy but limits the capacity of the line and generators by heating and has a bad effect on generator regulation.

The direct current motor has an advantage in this respect, the power factor being, of course, always unity.

*Safety.* The induction motor is to a large extent self-protecting. If it is subjected to such a heavy overload that it stalls and if for any reason the circuit breakers fail to open, it possesses sufficient inductance to keep the currents within such limits that the primary winding will not be burnt out unless the overload is continued for some time. When the overload is removed the motor immediately starts. This property is especially valuable, if, as in a case which came under the writer's notice, the motor's ordinary load is 50% overload, and the attendant finds it troublesome to renew the fuses every time it stalls, and solves the difficulty by "fusing" with No. O copper. If a direct current motor were subjected to such treatment it would of course mean a burnt-out armature, with subsequent adjournment to the repair shop.

Electric drive is used in many places where all danger of sparking must be absolutely eliminated, for instance, in the coal-grinding buildings of Portland cement mills. For such work the direct current motor cannot be considered, for no matter how well designed the motor may be, the commutation is liable to give trouble, with consequent danger of explosion and loss of life. For operation under these conditions the squirrel cage induction motor is well suited. The only electrical connections on the motor are the terminal board connections to the line, and these are completely insulated. The autostarter, consisting of a two-throw switch and pair of autotransformers, is completely enclosed and the switch contacts are under oil.

*Cost.* In the matter of cost the induction motor has an advantage in sizes over 10 h.p. for 60 cycle motors. According to figures furnished by one of the Canadian companies, the saving in initial cost of the 60 cycle induction motor over the direct current shunt motor in sizes between 10 and 100 h.p. amounts to between and 10 and 15%. 25 cycle motors are, of course, more expensive than 60 cycle motors, and for 25 cycle installations the saving is not so great.

From the above brief summary it is evident that it is impos-

sible to state broadly that either type of motor is better than the other. Each has its own merits and drawbacks, and the question as to whether direct or alternating current drive shall be installed in an industrial establishment must be settled by the existing conditions in each case.

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## THE MEASUREMENT OF POWER FACTOR IN THREE-PHASE CIRCUITS

CHAS. H. HUTTON, '07

The following method has been found quick and accurate for calculating the power factor in three phase circuits such as are usually met in commercial work with induction motors, transformers, etc. It possesses the additional advantage that only two quantities are necessary, watts and either volts or amperes in order to find the power factor and the other unknown quantity.

In the following theory, the endeavor has been to use only elementary relations so that the reader will find nothing not taken up

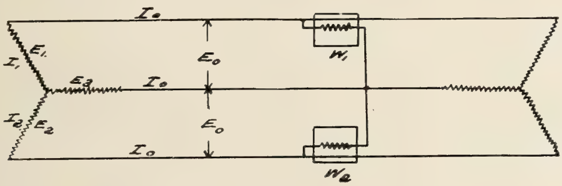



*Figure 1.*

in the lecture room, and at any rate he may turn the results obtained to his practical advantage.

In any single phase circuit the fundamental relation for power is

$$P = E_0 \, I_0 \cos \alpha \quad . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

where $P$ = power in watts, $E$ = *R.M.S.* volts between lines, $I$ = *R.M.S.* amperes in line, $\alpha$ = angle of space displacement between $E$ and $I$, $\alpha$ = power factor of the circuit.

To find an expression for the power in a three phase circuit, a circuit may be assumed as represented in Fig. 1. The power in any branch is $P = E \, I \cos \alpha$, hence the power in branch 1 of the star winding Fig. 1 is $P_1 = E_1 \, I_1 \cos \alpha$ and the total power $P$ is the sum of the three individual powers $P_1 + P_2 + P_3$. thus

$$P = E_1 \, I_1 \cos \alpha_1 + E_2 \, I_2 \cos \alpha_2 + E_3 \, I_3 \cos \alpha_3$$

For balanced loads $E_1 = E_2 = E_3$ and $I_1 = I_2 = I_3$ and hence $P = 3 \, E_1 \, I_1 \cos \alpha_1$. Now $I_1 = I_0$ = current in the line.

$E_1 = \dfrac{E_0}{\sqrt{3}}$ where $E_0$ = voltage measured between any two lines, hence

$$P = 3 \frac{E_0}{\sqrt{3}} \, I_0 \cos \alpha_1 = \sqrt{3} \, E_0 \, I_0 \cos \alpha_1 \quad . \; . \; . \; . \quad (1)$$

It is necessary now to prove that the wattmeters as connected in Fig. 1 measure this power $P$. Since the delta e.m.f. across the pressure coil of a wattmeter is displaced from the star current in the current coil, it is evident that a wattmeter will not measure the power of one individual phase only, but it may be proven as in the following that the algebraic sum of the two indications so mentioned is the true power $P$ as defined above.

Referring to Fig. 2, which shows the relations of current and voltage in the circuit Fig. 1, we have the vector $AB$ representing

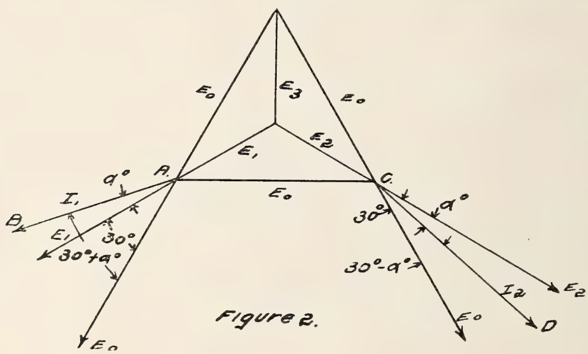



Figure 2.

the current $I_1$ lagging $\alpha°$ behind $E_1$ and $CA$ representing the current $I_2$ lagging $\alpha°$ the same amount behind $E_2$.

Then the power measured by wattmeter 1 is $W_1 = E_1 I_1 \sqrt{3} \cos(30° + \alpha)$, and since $E_0 = \sqrt{3} E_1$ and $I_0 = I_1$, $W_1 = E_0 I_0 \cos(30° + \alpha)$.

Similarly $W_2 = E_0 I_0 \cos(30° - \alpha)$ since the angle of phase displacement between $E_2$ and $I_2$ is $(30° - \alpha)$.

The algebraic sum of the readings of the two wattmeters is $W_1 + W_2 = E_0 I_0 [\cos(30° - \alpha) + \cos(30° + \alpha)]$.

$$= E_0 I_0 \, 2 \cos 30° \cos \alpha$$

$$= E_0 I_0 \, 2 \frac{\sqrt{3}}{2} \cos \alpha$$

$$= \sqrt{3} E_0 I_0 \cos \alpha$$

$$= P.$$

Hence the algebraic sum of $W_1$ and $W_2$ is equal to the three phase power $P$.

Further,

$$\frac{W_2}{W_1} = \frac{\cos(30° - \alpha)}{\cos(30° + \alpha)} \quad \ldots \ldots \quad (2)$$

It may be proven in a similar manner to the above that

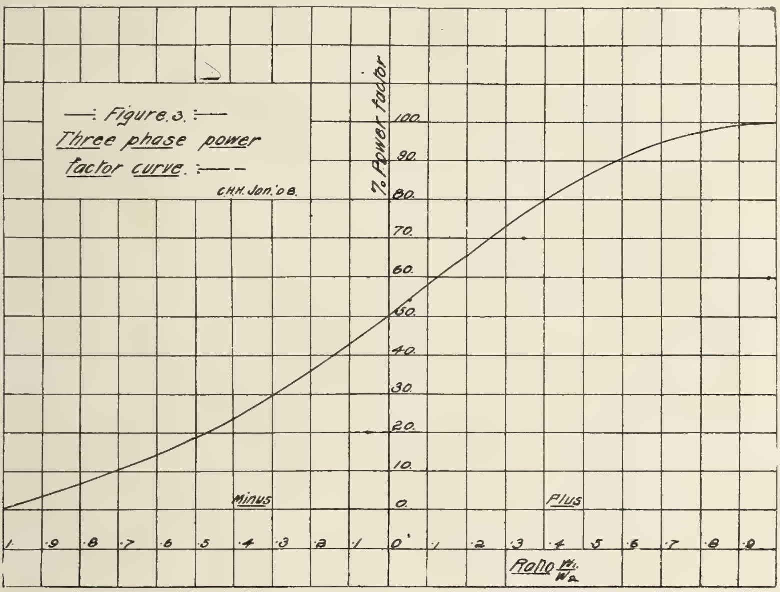
$$W_2 - W_1 = E_0 I_0 \sin \alpha.$$

Hence $\dfrac{W_2 - W_1}{W_2 + W_1} = \dfrac{E_0 I_0 \sin \alpha}{\sqrt{3} E_0 I_0 \cos \alpha} = \dfrac{\tan \alpha}{\sqrt{3}}$.

$$\text{Hence } \tan \alpha = \sqrt{3}\,\frac{W_2 - W_1}{W_2 + W_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

From this cos $\alpha$ may be determined since tan $\alpha$ is known. An easier way to find the power factor cos $\alpha$ is to use the curve Fig. 3 which has been plotted from the equation (2) above by substituting valves of $\alpha_1$ and finding the corresponding relations between $W_2$ and $W_1$. Having found the power factor from the ratio of wattmeter readings and the curve, and knowing either volts or amperes the other may be calculated from formula (1).

Some difficulty may arise in knowing when the wattmeter indicates negative power since the pressure coil must be always connected so as to give a positive reading. This may be easily




avoided by increasing the load on the circuit, when the wattmeters, if correctly connected, will indicate a corresponding increase in power. When using a polyphase meter, readings of $W_1$ and $W_2$ may be obtained by removing the small pressure plugs at the base of the instrument, one side for $W_1$, other side for $W_2$.

To illustrate the use of the curve the following examples are given :

I. $W_1 = 4600, \quad W_2 = 9000$

$$\therefore \frac{W_1}{W_2} = \frac{4600}{9000} = .51$$

corresponding to .51 we find the power factor of .867.

II. $W_1 = -4600, \quad W_2 = +9000$

$$\frac{W_1}{W_2} = \frac{-4600}{+9000} = -.51$$

corresponding to $-.51$ we find the power factor of .181.

# WATTMETERS AND THREE-PHASE BALANCED LOADS OF VARYING POWER FACTOR

H. W. PRICE, B.A.Sc.

The rate at which energy is transferred through a three-wire, three-phase circuit can be measured by two indicating wattmeters. If the load be 100% power factor and balanced, each wattmeter will indicate half the load, if not of 100% power factor the meters indicate unequal portions of the load.

Not long ago an electrical engineer called on the writer in regard to difficulty with two wattmeters on a switchboard serving a three-phase rotary converter. The board was liberally supplied with instruments, including a power factor meter. The load was balanced, that is the three line currents were equal, also the three between-line voltages. The wattmeters, however, persisted in indicating very unequal shares of the load, in fact, of a total load of 880 kw. one meter indicated 492 kw. and the other 388 kw. The blue-prints showed correct connections of the meters to the lines through shunt and series transformers, and the engineer was certain that actual connections were according to the prints. The meters had twice been checked against standards, and were correct. A question as to power factor was answered by this statement: "The power factor meter shows always about 98%, which for all practical purposes is 100%, and the meters should share the load equally. They must be out of calibration and yet they check against the standards. Something is wrong." A little calculation showed that those conclusions with regard to 98% power factor were not as reliable as the meters, for the variation of 2% from unity power factor accounted for an indication by one meter 25½% in excess of that of the other, or 490 and 390 kw. When the field excitation of the rotary was adjusted to cause 100% power factor, each meter indicated 440 kw.

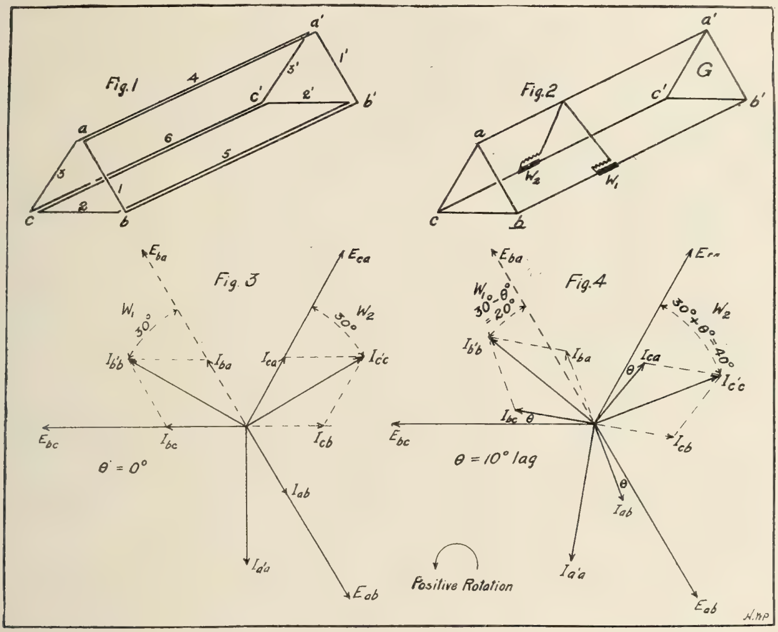
Consideration of facts and underlying principles in connection with the above forms the subject of this paper.

Fig. 1 shows in diagram a three phase generator connected to a three phase load. Each phase is separate, having two lines of its own. The three generator windings are mechanically located on the armature so that the e.m.fs. 1′, 2′, 3′ attain their maximum instantaneous values in regular sequence, 1′, 2′, 3′, and equally spaced as to time, that is, the three e.m.fs. from the three alternator windings may be suitably represented by three sine waves 120° apart. The wave of e.m.f. from commercial generators is approximately of sine form. These voltages cause currents, 1, 2, 3, also represented by sine waves 120° apart. If the pairs of lines at 4, 5, 6 be replaced by three single conductors, the current in 4, for example, must be the resultant of currents 1′ and 3′ or 1 and 3,

hence will also be a sine wave but not in phase with either 1 or 3. Similarly will 5 and 6 carry resultant currents.

In proceeding further it is necessary to adopt a definite method of describing vectors to avoid confusion and mistake. If $p$ and $q$ be two points $E$ volts apart, $p$ being higher in potential than $q$, then voltage $E$ may be described in magnitude and sense by $E_{pq}$. The resulting current from $p$ to $q$ would be called $I_{pq}$. If it were desired to consider the current as from $q$ to $p$, the description would be $-I_{pq}$ or $I_{qp}$, etc.

In Fig. 2 let it be assumed that currents marked $a'a$, $b'b$, $c'c$ $ab$, $bc$, $ca$, and voltages marked $ab$, $bc$, $ca$, are positive, also that




voltages $E_{ab}$, $E_{bc}$, $E_{ca}$ pass through their maximum positive values in the order named.

Fig. 2 diagramatically represents the generator and load, and two wattmeters, $W_1$ and $W_2$, necessary to measure the load.

In Fig. 3, $E_{ab}$, $E_{bc}$, $E_{ca}$, are represented as equal vectors 120° apart, and will attain maximum positive values in the order named if counter-clockwise rotation be assumed. At 100% power factor these voltages cause equal currents $I_{ab}$, $I_{bc}$, $I_{ca}$ in phase with the corresponding voltages. Current $I_{b'b}$ toward point $b$ must at all instants be equal to the sum of currents $I_{ba}$ and $I_{bc}$ away from $b$, that is

$$I_{b'b} = I_{ba} + I_{bc} = -I_{ab} + I_{bc}$$

Current $I_{ba}$ is shown dotted and opposite to $I_{ab}$. Current $I_{b'b}$ is the resultant of $I_{ba}$ and $I_{bc}$. Similarly may be found currents $I_{a'a}$,

and $I_{c}{}^{1}{}_{c}$. The wattmeter $W_1$ will indicate because of current $I_{b}{}^{1}{}_{b}$ through its series coil and a small current through its shunt coil in phase with $E_{ba}$ (opposite to $E_{ab}$) or

$$W_1 = E_{ba}\, I_{b}{}^{1}{}_{b} \cos 30^\circ$$

Since $E_{ba} = E_{ca}$ and $I_{b}{}^{1}{}_{b} = I_{c}{}^{1}{}_{c}$ in magnitude, $W_1 = W_2$ at 100% power factor.

Suppose, as represented in fig. 4, the power factor such that the current in each leg of the load must lag $\theta^\circ$ behind the voltage causing it. Evidently the wattmeters must alter their indications so that

$$W_1 = E_{ba}\, I_{c}{}^{1}{}_{c} \cos (30^\circ - \theta^\circ)$$

and

$$W_2 = E_{ca}\, I_{c}{}^{1}{}_{c} \cos (30^\circ + \theta^\circ)$$

because the change in power factor has caused all current vectors to shift $\theta^\circ$ backward with regard to the voltage vectors. In wattmeter $W_1$ at 100% power factor current $I_{b}{}^{1}{}_{b}$ through its series coil *leads* by 30° in electrical time-phase the voltage $E_{ba}$ across its shunt winding while at power factor such that $\theta = 10^\circ$ lag the current $I_{b}{}^{1}{}_{b}$ leads voltage $E_{ba}$ by only 30°—10° or 20°. Wattmeter $W_2$ at 100% power factor indicates the watt product of voltage $E_{ca}$ and current $I_{c}{}^{1}{}_{c}$ which *lags* 30° behind $E_{ca}$, while at $\theta = 10^\circ$ lag there is an increased phase displacement of 30°+10° or 40°. Evidently then with lagging currents the indication of $W_2$ must continue to decrease with increasing values of $\theta$ until at $\theta = 60^\circ$ reading $W_2$ becomes zero since $30^\circ + \theta^\circ = 90^\circ$. Greater lag causes negative indications, to read which the pressure connections of the wattmeter must be reversed. Similarly with leading currents and power factors in the neighborhood of 50%, wattmeter $W_1$ shows small indications because the lead of $I_{b}{}^{1}{}_{b}$ with regard to $E_{ba}$ is about 90%.

From these facts the following statements are true of balanced loads:—

1. With power factor 100%, $W_1 = W_2$, hence each meter indicates one-half of the total load.

2. With lagging currents and power factors between 100% and 50%, $W_1$ indicates more than $W_2$, both indications are positive, and $W_1 + W_2 =$ total load.

3. With lagging currents and power factor 50%, $W_2 = 0$ since $\theta = 60^\circ$, hence $W_1$ indicates the total load.

4. With lagging currents and power factors less than 50%, $W_2$ becomes negative and $W_1$ indicates more than the total load. Hence it is necessary to reverse the voltage connections of $W_2$ to read the meter, and the load is $W_1 - W_2$.

5. With the leading currents, and varying power factor, the same statements apply with $W_1$ and $W_2$ interchanged, because the sign of $\theta$ is reversed. $\theta$ means lag angle of current with regard to voltage causing it. Leading current has therefore a negative lag.

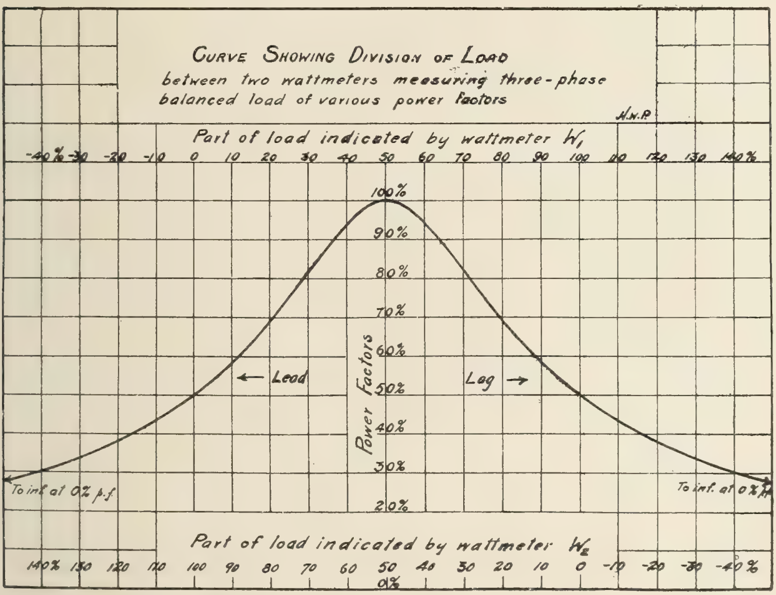
In operating rotary converters or synchronous motors at any load, the power factor of the input currents may be varied at

pleasure by adjustment of field excitation. Over-normal excitation causes leading currents, and under-normal excitation lagging currents. The variation in value of the coefficients cos $(30°+\theta°)$ and cos $(30°-\theta°)$ must account for changes in relative values of $W_1$ and $W_2$, since any change in power factor or load resulting in altered volt-ampere input causes the same change in $E_{ba} I^1_b$ as in $E_{ca} I^1_c$

Example :— Power factor 95%, cos $\theta = .95$, $\theta = 18°$, cos $(30° - 18°) = .978$, cos $(30° + 18°) = .669$, cos $12°$ + cos $48° = 1.647$, part of load indicated by $W_1 = \frac{.978}{11.647} \times 100 = 59.5\%$, by $W_2 = \frac{.669}{1.647} \times 100 = 40.5\%$.

In this manner, values for different power factors have been calculated, and results are shown in the curve herewith.

An appreciation of the facts illustrated by the curve will




prevent one from making the mistake of a certain road man who, after installing two recording meters on a panel supplying a group of three phase induction motors, observed one meter running "slow," and proceeded to remedy the trouble by "doctoring" that meter till it ran at the same speed as its mate.

# AN ELECTRICAL PROBLEM GRAPHICALLY SOLVED

H. W. PRICE, B A.Sc.

*Problem.*—A question which may be of interest was submitted to the writer a few weeks ago. A manufacturer was using induction motors to operate a large factory, and found the average load to be 200 kilowatts at 60% power factor. To improve the power factor, it was proposed to install a synchronous motor of probably 75 horse-power to be used as a motor and as a "synchronous condenser." Question: "What will the power factor be if that motor is installed?"

The information being incomplete, it was ascertained further that 200 kilowatts would supply every requirement and induction motors would be removed in so far as the synchronous motor could replace them.

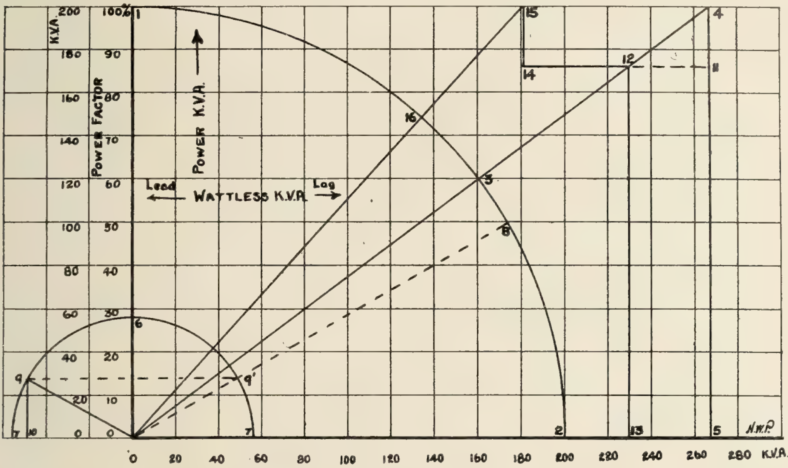
*Solution.*—See figure. On a sheet of section paper choose point 0. From it draw vertically a line 100 parts long, and describe the quadrant 1, 2. The quadrant will serve very conveniently for reading power factors when supplemented by a vertical scale of power factor as indicated. The direction 0, 1 will serve to represent power input to the plant on a scale as marked, while direction 0, 2 may represent wattless input due to power factors less than 100%.

The power input is 200 k.w. at 60% power factor. To find the power and wattless components of the load, locate the 60% line which intersects the quadrant at 3. From 0 draw 0, 3 produced to intersect the 200 k.w. line at 4. Then 0, 4 represents the k.v.a. (kilovolt-ampere) input to the induction motors, of which the energy component is 5, 4=200 k.w. and the wattless component is 0, 5=267 k.v.a. The synchronous motor is desired to reduce the objectionably large wattless lagging component by neutralizing it so far as possible by wattless leading component.

The rated capacity of the proposed motor is 75 h.p. or 55 k.w. From 0 at radius 0, 6=56 k.w. draw the semicircle 7, 6, 7, which is the locus of the rated k.v.a. capacity of the motor. If the motor were operated at 100% power factor, it would be capable of delivering 56 k.w. continuously without overheating. If its field were over-excited so as to cause the receipt of leading currents, the load would of necessity be reduced to avoid overheating so that the input k.v.a. could not exceed 56 k.v.a. Since the reason for the change in machines is necessity for wattless leading currents to neutralize lagging currents, it is desirable to operate the synchronous motor at fairly low power factor, say 50%. This value permits the motor to deliver one half its rated output and also take leading currents to the extent of 87% of its rated current capacity. The 50% power factor line locates point 8, hence points 9′ and 9 on the capacity circle of the motor. Then with over excited field 0, 9 is the k.v.a. input to the motor, of which 10, 9 is the power input and 0, 10 the

wattless k.v.a. input due to leading currents caused by the suitably over-excited field.

The induction motor load 5, 4=200 k.w. may now be reduced by 4, 11=9, 10=28 k.w. to be carried by the synchronous motor, that is 28 k.w. or 37½ h.p. of induction motors may be removed. Since these motors operate at 60% power factor, their removal reduces the wattless k.v.a. input by 11, 12, leaving 13, 12=172 k.w. load for induction motors at 60% power factor. The wattless lag-




ging input 0, 13 of these motors will be reduced by the wattless leading input 0, 10=12, 14 to the synchronous motor, and the latter will deliver power to the extent 14, 15=10, 9.

Hence the new motor, if operated at full load current at 50% power factor with over-excited field, will reduce the total k.v.a. input from 0, 4 to 0, 15 for the same load, 200 k.w., and raise the power factor as shown by intersection at point 16, to 74%

# PRACTICAL APPLICATIONS OF THE GYROSCOPE

T. R. LOUDON, B.A.Sc., '05.

It is not proposed in this limited space to deal mathematically with the action of the gyroscope. Although it is almost impossible to explain the curious properties of this instrument in any other than a deeply involved mathematical manner, a few hard and fast statements may be made as to what actually does and will happen under certain conditions, irrespective of the reason for such.

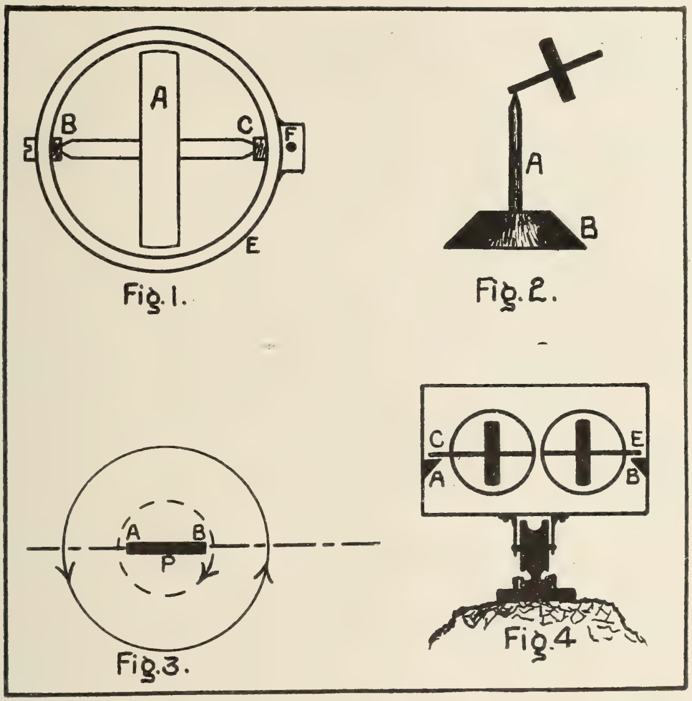
Fig. 1 shows diagramatically the construction of a simple gyroscope. The fly wheel A is mounted in such a manner that it revolves in a plane perpendicular to the frame *E*. If now, the fly wheel be made to rotate at a comparatively high rate (by means of a string wound on the axle) and the frame *E* be held firmly in one's hands, the whole contrivance, simple and harmless looking in the extreme, seems to have become imbued with life. It will be noticed that if the apparatus be moved about in such a manner as to keep the fly wheel always revolving in a plane parallel to its initial plane of rotation, that no activity is manifested, but let the observer try to change the plane of rotation and, instantly, there will be felt a resisting force whose magnitude depends upon the mass of the fly wheel and the rate of revolution. Briefly, it may be said that a body in rotation resists all attempts to disturb its plane of rotation to any other plane than that parallel to the initial plane.

As a first experiment, let a piece of stout cord be tied to the frame of the gyroscope at one end of the axis of rotation (*B* or *C*, Fig. 1) and the string be whirled so that the instrument describes a circle; under the influence of centrifugal force, the whole mechanism tends to rise to such a position at the end of the taut string that the fly wheel revolves in a plane parallel to the plane of the circle described. Another interesting experiment is illustrated at Fig. 2. *A* is an upright steel bar sharpened to a point at one end, the other end being firmly set into a weighted base *B*. The fly wheel of the gyroscope is set in rotation and the small conical seated hole *F* in Fig. 1 is then placed over the pointed upright *A*, Fig. 2. Apparently, in direct opposition to the laws of gravity, instead of falling down, the instrument becomes, as it were, self supporting, balancing on the pivot *A*, Fig. 2, at the same time slowly revolving about on axis through the vertical upright *A*. This last experiment is simply the case of the ordinary top which maintains its equilibrium as long as it revolves with sufficient rapidity.

As a result of its tendency to keep its initial plane of rotation, the gyroscope may be used to show or make evident the diurnal rotation of the earth on its axis. It will, perhaps, be easier to see how this is if one imagines oneself situated exactly at either of the earth's poles. In Fig. 3, *A B* represents the fly wheel of the in-

strument placed so that its plane of rotation contains the axis of the earth, *P* being say the north pole. The direction of the earth's rotation is indicated by the arrow heads on the full line circle. The gyroscope is set in action and as the earth rotates, the instrument keeping its initial plane of rotation, is, as it were, left behind with the apparent result, as far as the observer is concerned, that the gyroscope seems to revolve slowly about a vertical axis (provision being made for such in the mounting) in a direction counter to what is now known to be the sense of the earth's rotation. This is indicated by the arrow head on the dotted circle.

Gyrostatic action has been made use of to give a horizontal




surface for navigator's observations. The first instrument of this kind was merely a top with a polished plane surface at its upper end. The top was set in motion and, of course, came to the vertical, thereby furnishing by its top surface a good horizontal plane. Schlick quite recently invented a gyroscopic instrument in which the fly wheel is run automatically by means of a small air turbine fed from a compressor. This contrivance maintains a horizontal plane surface for any length of time, the air being compressed by a hand pump.

The so-called "bursting" of fly wheels is generally and quite reasonably attributed to improper design of the material which

has to resist centrifugal force. There have, however, been numerous cases in which fly wheels have ruptured and in which the fractured sections were afterwards shown to be both of sufficient area and of flawless material. It is, therefore, quite evident that there must have been some force at work other than mere centrifugal action.

If one considers the usual methods of mounting fly wheels, the revolutions at which they are run, and their massive construction, it is at once seen that these wheels when running are subject to the laws that govern gyroscopic action. Suppose the shaft bearings to wear or work loose from improper supervision, it will not be long before a very serious movement of the shaft takes place as it rotates. Going back to the simple gyroscope, it was seen that if one tries to disturb the plane of rotation to some plane other than parallel to the initial plane, the disturbing force is at once resisted. This is exactly what happens when the plane of rotation of the fly wheel is disturbed by the movement or jumping of the shaft in its bearings—the disturbing force being resisted with the result that undue stresses are brought into action in the spokes and rim. Experiments with flexible rims show the action of these forces very plainly, the wheel being very much distorted when its plane of rotation is disturbed. Of course, the actual case cannot be compared to this, but in high speed engines, it is easy to imagine the effect of the shaft jumping about and causing reversals of the deforming stresses, causing, in fact, tension then compression and so on till weakening takes place and finally rupture from the combined centrifugal and gyrostatic forces.

It will be remembered that a few years ago when the torpedo destroyer "Viper" of the British Navy foundered after breaking in half, that the accident was attributed to the gyrostatic action of the high speed steam turbines. Although this theory is now discredited, it is still undisputed that the presence of a turbine with its rotor revolving at a high rate does give rise to serious straining stresses as the vessel pitches and tosses in a sea; that is, as the plane of rotation of the turbine is disturbed.

Passing from what might be termed these theoretical considerations to the practical side of the gyroscope, perhaps the most wonderful and certainly the most useful development is the recent Mono-rail car invented by Mr. Louis Brennan, the inventor of the famous torpedo which bears his name, the main point of which is a gyroscopic steering gear.

This mono-rail car, as its name implies, runs on a single rail; not only this, but it will run on a single cable suspended in mid air, around curves which no ordinary locomotive, double or mono-rail, could ever attempt to round, up grades phenomenal, in fact, anywhere a single rail or cable can be laid or stretched by practical means. Stripped of its historical development, the construction of the invention is as follows: The body of the car may be such as is ordinarily employed, except that on the trucks only one

double flanged wheel per axle is used. Somewhere in the body of the car is placed what is nothing more or less than a gyroscope designed to fulfil certain requirements, and it is this apparatus that holds the car upright on its single rail.

Before going into the construction of the steadying apparatus, it is perhaps better to consider what forces have to be overcome by the gyroscope. There is first the very self evident necessity of balancing the car in an upright position on the single rail. Secondly, there is the centrifugal force acting on the whole car when rounding a curve; and lastly, the tendency of the gyroscope itself, considered apart from the car, to turn over when acted upon by centrifugal force. To keep the car upright is a comparatively simple problem, all that is required being a single gyroscope mounted so that the fly wheel rotates in the central longitudinal plane of the car. As long as rotation is kept up, and provided the fly wheel is sufficiently massive, the car cannot overbalance on it single line of wheels. It is, in fact, very much like a large top only that instead of resting on a single point, it has four points of contact. Taking next, the last of the three forces to be counteracted, namely, the tendency of the gyroscope to turn over when under the influence of centrifugal force; it was pointed out that if a gyroscope be attached axially to a string and swung in a circle, that it tended to rise under the action of centrifugal force, into such a position that the fly wheel would rotate in the plane of the circle described. When the gyro-car comes to a curve, the case is analogous to the gyroscope tied to the piece of string and whirled in a circle. Centrifugal force acts on the balancing apparatus of the car with the result that the gyroscope will tend to turn over into such a position that the plane of rotation is parallel to that of the circle or curve described, resulting in the car being toppled over. To get over this difficulty, two gyroscopic fly wheels are mounted side by side in the car and are given rotations in opposite senses with the result that when acted on by centrifugal force, each gyroscope tends to turn over but since their fly wheels are of equal mass and have rotations in opposite directions, they counteract one another thus, as far as the revolving fly wheels is concerned, the car would continue on its journey; but there is still another obstacle to be overcome. The whole car itself tends to upset when rounding a curve just as it would on any double track railway were the outer rail not elevated. This is obviated by having the axles of the fly wheels project beyond their bearings as shown at $C$ and $E$, Fig. 4, and placing on the car frame two blocks $A$ and $B$. Now, when the car tends to turn over, either the block $A$ or $B$ comes in contact with the end of the axle $C$ or $E$. The whole gyroscopic apparatus then tends to rise up like a top on the axle $C$ or $E$ depending on which way the car tips, thus pressing on $A$ or $B$ respectively, in fact, resisting the disturbing force. The result is that the car leans inward as it goes around the curve. Of course, Fig. 4 is a mere diagram as the actual con-

struction has not yet been made public, having no doubt embodied in it many very fine points as obstacles not evident at first sight but which would have to be overcome in the practical case. One very curious thing is the effect of a load placed on the side of the car. Instead of dropping down to the side loaded, the car rises up on that side, this being due, of course, to the gyroscopes resisting the disturbing force.

The great point in favor of such a car is the entire elimination of friction when rounding curves. In a test made on the experimental gyro-car, five feet nine inches long by one foot six inches wide, curves were run over such that the front truck had arrived on the tangent before the back wheels struck the curve. In fact, the only limitation seems to be the distance between the single wheels on each truck. The gyroscopes in this case were run at a revolution of about 7,000 per minute and constituted merely five per cent. of the total weight of the car. The inventor claims, however, that in the practical case, a rate of only 3,000 R. P. M. need be kept up and that balance may be maintained at 850 R. P. M.

"What happens if the gyroscopes stop?" is the natural question of the practical man. The fly wheels are so beautifully mounted in a vacuum that should their driving power be disabled, they still continue to revolve for forty-eight hours and will maintain the car in an upright position for twelve hours. Even at this the doubter objects that the fly wheels themselves may be disabled and to this there is no answer except that, so far, locomotion has not been freed entirely from its dangers no matter what form it takes and certainly the gyro-car is not claimed to be perfection in this direction.

Naturally, the question arises, if a car may be maintained upright on land, why not keep a boat vertical by the same means? This problem has been experimentd with and has proven quite successful. The frame of a large gyroscope was mounted on horizontal pivots so that it could swing fore and aft as the vessel rose and fell to the sea. The fly wheel was then placed in the frame with its axis vertical so that its plane of rotation being horizontal, the vessel could not roll, which, no doubt, would be a relief to passengers.

It may be pointed out in closing that because of the high rate of revolution necessary in order to get good results with a gyroscope, the frame must be of very solid construction so as to hold the bearings firmly. It can readily be pictured what havoc a fly wheel running at a rate of 7,000 revolutions per minute would create by getting loose from its bearings.

# IRON RANGES OF THE NIPIGON REGION

A. P. COLEMAN, M.A., Ph.D.

Almost all the areas mapped as Huronian in Northern Ontario contain more or less of the iron formation, though up to the present only three of these areas can be said to have furnished iron mines, Michipicoten, Atikokan and Moose Mountain. The Helen mine is the only one working on a large scale. Naturally the iron ranges of the other regions have attracted much attention from prospectors and geologists, so that most of them have been more or less carefully explored and mapped, without, however, disclosing up to the present any large ore bodies.

There are several iron ranges on, or near, the shores of lake Nipigon on which exploration work has been done, especially two on the east and north-east of the lake, the Poplar Lodge and the Red Paint River ranges. On the former a good deal of stripping and diamond drilling have been done, mainly by the Lake Superior Corporation, under the general direction of Prof. Willmott, and by an unknown company represented by Mr. Flaherty.

During the past two summers the geology of these two ranges has been worked out by myself, with the assistance of Mr. S. E. Moore, and Mr. Green, for the Bureau of Mines of Ontario; and it is proposed to give a sketch of the relationships in this paper.

The Poplar Lodge iron ranges are three in number, near the east shore of Lake Nipigon, northern, central and southern, but as one goes inland they seem to come together so as to form only one range, running somewhat north of east and ending about twenty-five miles from the shore. The three bands of iron formation near Poplar Lodge, an old Hudson Bay post, are the parts which have attracted most attention, though claims have been taken up as far north-east as the range is known to run.

Owing to widespread old lake deposits of sand and gravel, and equally widespread swamps and muskegs, the solid rocks of the region are concealed over more than half the surface; but in general they have been found to consist of green and gray schists with the banded silica and iron ore of the iron formation, belonging to the Keewatin, the lowest known geological formation, and conglomerates, representing the Lower Huronian. Through these schistose rocks, now generally titled nearly on edge by mountain folding, various eruptives have come up, especially great masses of diabase supposed to belong to the Keweenawan age. The three bands of iron formation run parallel to the schistose structure of the Keewatin and Huronian, and, no doubt, represent the top of the Keewatin.

It is rather curious that the three bands, which run parallel to one another, only a mile or two apart, have very different characters. The northern range, which is not very wide, runs along the

north side of Sturgeon River against a range of greenstone hills, and consists of quartzitic looking silica with magnetite and also a little hematite. The range is too narrow and lean, so far as known, to have any economic value.

The central range lies in low land and is much covered with drift deposits and peat, but has been shown to be about a third of a mile broad and two or three miles long. In this range there is no magnetite, so that the compass is not at all disturbed, the whole of the iron existing as hematite, red or black and lustrous, in bands alternating with red jasper and other varieties of silica. The formation is most attractive in appearance, and has been crumpled in the most elaborate way. Unfortunately the bands of ore are never very wide, seldom more than an inch or two, though the hematite itself is of excellent quality. Considerable parts of the formation might run 35 per cent. of iron, silica being the other ingredient; but no important tonnage of higher grade ore can be seen on the surface or has been demonstrated by drilling. If there are ore bodies of high grade and good size they have not yet been uncovered.

The southern range is magnetic, like the northern range, and being of harder materials than the central range, is more apt to rise as ridges. Here the magnetite is banded with quartzitic silica in some places, but often lies between thin bands of slate. There is a little red jasper and hematite present also; and the range is in some places two or three hundred feet wide. Parts of the magnetite are high enough in iron to make a marketable ore, but whether large deposits exist has not been demonstrated. The inland extension of these ranges, along Wendigokan Lake and farther to the north-east, is of a mixed character, containing both magnetite and hematite; but does not differ very greatly from the ranges just described.

The other iron range geologically mapped lies some distance inland from the north-eastern end of Lake Nipigon, near the head waters of Red Paint River. The projected line of the new Transcontinental Railway runs close to several of the outcrops, so that in a few years access will be easy. At present the region can be reached most readily by canoe on the small and winding Red Paint River. Some stripping and drilling is being done under the direction of Mr. Flaherty, who was enterprising enough to take in all the parts of a diamond drill in a large Peterboro' canoe.

The iron formation near the watershed between Lake Nepigon and Hudson Bay consists partly of jasper and hematite and partly of gray quartzitic looking silica with magnetite, the whole enclosed in green or gray schistose rocks or greenstones of the Keewatin. The beds are, as usual, nearly vertical in attitude, and in some places the band is more than 100 yards wide, but with a good deal of schist interbedded with the ore and silica. Here, as in the Poplar Lodge region, there are long stretches of iron formation,

but up to the present no deposits rich enough to be classed as marketable ore have been found.

In the American iron ranges of Keewatin age it has been the usual experience that the iron formation occurs in synclinal bands, but that ore bodies are found only under special conditions, where a basin has been cut off by dikes or in some other way affording a cavity in which iron compounds, leached by descending waters from the lean iron range above could accumulate. The ore bodies then are of secondary origin, magnetite, or hematite, or siderite, being dissolved from the banded silica or other iron range rocks and redeposited in the basin, generally as hematite or limonite.

In Ontario we have an instance of the same kind in the Helen Mine, at Michipicoten, where a mixture of brown and red hematite has been deposited in a basin at the bottom of a narrow syncline, the materials being derived from banded iron ore and silica, siderite and also pyrites.

The other two important known bodies of iron ore in Ontario, the Atikokan and Hutton township deposits, are, however, of a very different type. They are parts of the iron range itself, rich enough in iron to be used as ores. They contain much less than usual of the interbanded silica, which is often replaced by a green hornblende rich in iron. They represent then locally enriched portions of the regular iron formation and not separate concentrations in basins beneath the leaner rock above.

In regard to the ranges east of lake Nipigon some parts of the southern range near Poplar Lodge come near to being a low grade ore, but most other parts of the iron formation are far too lean to be used as ores.

In this region the best hope of ore lies in exploration of the low ground, covered with drift or swamp, where deposits of secondary hematite or limonite may lie concealed.

It has proved very disappointing that such extensive development of the iron formation as one finds in Northern Ontario have so far furnished only three important bodies of ore, in contrast with the many great mines south and west of Lake Superior in Michigan, Wisconsin and Minnesota, from a smaller extent of the formation.

Why our iron ranges should be so much poorer is hard to understand, unless President Van Hise's theory is correct that our region has been more powerfully scoured by the ice sheets of the glacial period, removing and mixing up with other glacial debris the ore bodies that once existed.

It may be, however, that the work of exploration has been too superficial up to the present, and that important ore bodies have been overlooked because buried under peat bogs or old lake deposits. Secondary ore bodies consisting generally of hematite or limonite have no effect on the dip needle, the instrument generally used to trace the iron formation when concealed in these ways. It shall be remembered that this method only proves the existence

of magnetite such as occurs interbanded with silica in the iron ranges and gives no hint of secondary iron ore bodies not containing magnetite.

It may require a large expenditure on stripping, test-pitting and diamond drilling to finally settle the problem of iron ore distribution on the ranges of Northern Ontario.

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## Editorial

**Will the Men of 1910 be "Slated"?**

"There is a very strong feeling current in our first year that the men of 1910 will be slated at their examinations in consequence of the lack of accommodation." The above is quoted from a contributed article in the last number of "Applied Science." There is no doubt that the article accurately stated the condition of affairs from the standpoint of the undergraduate. There is also no doubt that the Faculty of Applied Science is shamefully overcrowded, that the classes are too large, that the laboratories are congested, that the student does not feel

that he is in direct touch with the lecturer and that he is losing heavily in consequence.

Nevertheless it is equally true that no one will be "slated" because of lack of accommodation higher up, since the spout is no more congested than the hopper.

But yet the fact remains that last year 35 per cent. of the men failed to pass the required examination, while over 50 per cent. of the remainder carried stars with them into their second year; only 65 in a class of 248 were able to attain the comparatively low honor standing required in the Faculty, and in many quarters a fixed opinion prevails that a certain percentage of the men must of necessity be plucked every year.

**Why do so Many Freshmen Fail?**

The question naturally arises, why this distinctly unfavorable showing? Is it the fault of the men, the curriculum or the teaching? Obviously something is seriously wrong. No one will argue that the class of students at the "school" are mentally inferior to those in the other faculties. All will admit that the teaching staff are doing remarkably good work, considering the circumstances. Our graduates go out into the world and hold their own in competition with those of other engineering colleges. Why, then, this slaughter of the innocents in their first year? The process of elimination has brought us to the curriculum. Is too much ground covered in the first year for the average student, with junior matriculation standing to thoroughly, or even satisfactorily, master the details?

The examination results seem to indicate there is. This view seems to be thoroughly established by the fact that in six years only two men of senior matriculation standing, or better, failed to pass the required examination, and practically all took honors.

**Should the Standard of Entrance be Raised?**

The ideal preparation for an engineering education is a literary and scientific course of a general nature, extending over three or four years. Living up to this ideal is impossible to the average student. Practically all authorities, however, agree that a thorough grounding in mathematics is absolutely essential. Doubtless there would be fewer failures if more personal attention were given to the men; that is, if secondary school methods were introduced. But the true reason seems to be the lack of proper preparation, not of accommodation. A large percentage of the students entering the school are too young, their minds are immature and insufficiently developed to deal with the interpretation of the abstract quantities constantly encountered in the first year. In a number of cases they have been rushed through their high school courses and have carried away with them an undigested mass of unrelated facts, producing in many cases what might be

called mental dyspepsia. Their memories have been developed at the expense of their reasoning faculties, in short they have not been trained to think.

This applies pre-eminently to mathematics. Unless the student has been very diligent his mind retains nothing beyond a chaos of formulae, hard to remember, and a few mechanical means of solving abstract questions; he is incapable of applying an equation to a practical problem; a formula has practically no meaning to him.

**Why is the Present Matriculation Standard too Low?**

That a man cannot be too well grounded in English may be accepted as axiomatic in all branches of education; that he cannot be too well grounded in mathematics is equally true in technical education. Economy of time is the only limitation. There has been a demand for years that lectures in English be added to our curriculum, but as it is already overloaded such a move has been deemed impracticable, until the course is lengthened by another year. As a result the graduates are seriously handicapped in their career.

Contracts, tenders, specifications, reports, are essential features of an engineer's business. He should have the ability to express himself concisely and accurately, second only to a lawyer. The present standard certainly does not give the matriculant this ability. However, apart from their culture values, the lack of languages will not hamper the student during his technical course. The essential feature is a thorough grounding in mathematics. Does the junior matriculation give this grounding? Most certainly not, since trigonometry, higher algebra, including progressions, variations, maxima and minima, and advanced geometry are not even touched. Nevertheless trigonometry is used in almost the first lecture in statics, and variation in dynamics. The result is the lectures, instead of being lectures in statics and dynamics, become lectures in mathematics. Time is lost by the lecturer; he cannot take time to drill on the mathematics, consequently when he proceeds into statical or dynamical aspects of the subject, a large percentage of his class are thinking of the mathematical side. They constantly fall behind and sink into the slough of despond.

Dean Galbraith in a paper read before the American Association for the Advancement of Science in 1897 said: "The student cannot afford the time involved in deferring the study of dynamics until he has acquired a working knowledge of calculus (now a second year subject). As a consequence he becomes confused regarding the origin of his difficulty, and possibly attributes to his ignorance of mathematics, misconceptions, the nature of which may be purely dynamical." It is about this time that the student becomes dissatisfied with his course and goes around lamenting, it is too theoretical; not practical enough.

Admitting that this putting the cart before the horse is not incongruous; that teaching mathematics sporadically, as required, is good educational principle, and the lost time, taken by a lecturer to teach another man's subject, is fair to the lecturer; does the teaching of mathematics as at present conducted give the student a good grounding in all necessary branches of the subject? Would not the time be better employed by raising the standard to an equivalent of the present senior matriculation and requiring the student to stay one year longer in the high schools? In other words, which will produce the better results, ten months' work in small classes, under strict supervision, or six months, in large classes, a few lectures a week, under no supervision whatever? Theoretically the present system should give a good foundation. Under ideal conditions with ideal students it would. But, unfortunately, we have to deal with neither. The average freshman newly freed from restraint will not work at full pressure from beginning. Hence, the disastrous results are shown by examination returns. It is true that by dint of cramming he may make the grade, only to suffer in his future work. It is the opinion of some of our most conservative professors that 33 to 50 per cent. of the senior year could not pass fair papers in first and second year mathematics.

**How do Successful Engineers Regard Mathematics?**

Mathematics is the foundation of a technical education; it is to an engineer what anatomy is to a surgeon, what chemistry is to an apothecary, what drill is to a soldier. We are pleased to call this "The Faculty of Applied Science." Is not a great portion of the first year spent in pure mathematics to the detriment of applied mathematics?

Mr. Ralph Modjeska, a prominent American engineer of foreign birth and training, in a paper read before the American Society for the Advancement of Science, referring to the teaching in mathematics argued along the following lines: The method of presentation should be such that the student knows the why and the wherefore of each operation, in other words that he learns to think mathematically. One does not know a foreign language unless he can think in that language. One does not know mathematics unless he can think mathematically. It is not necessary for this to go up in higher mathematics, but it is necessary to be thoroughly drilled in the elementary principles of this subject. These elementary principles should become a second nature to the student just as language becomes a second nature when it is thoroughly acquired.

Problems arise every day in the practice of an engineer which a mathematical mind can solve without going into calculations, the principles of maxima and minima those of least work and others are invaluable in assisting at a logical solution of many problems without the use of paper and pencil; but, in

order that they may be applied one has to be able to think mathematically.

**When Should the Change be Made?**

An agitation is being carried on in all of the faculties which has for its object the raising the standard of entrance to senior matriculation. In Arts the endeavor is to shorten the University course. In Medicine the object appears to be to still further close the profession. In Applied Science we need the change because the average student suffers throughout his course under present conditions.

Are we dealing honestly with the parents of the province, who furnish the money to send their sons to college? We accept the applicants and then calmly slaughter the freshmen at their examinations. Should not the case of the "school" be considered separately and immediately?

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The Department of Applied Mechanics announces that it is desirous of forming a collection of photographs and drawings of bridges and buildings, completed or under construction, which exhibit features of interest from an engineering point of view. While the illustration of current practice is of chief importance, it is hoped that the older structures, showing the methods of construction in vogue many years ago, and which are of interest in a study of the evolution of design, will be represented. Graduates and others interested who desire to help in the work are requested to send in any photographs or drawings which they think would be of interest.

## WHAT WE ARE DOING

Our readers will be interested to learn of the election by acclamation of our esteemed Dean, Dr. Galbraith, to the presidency of the Canadian Society of Civil Engineers for the year 1908. The privilege of presiding over the deliberations of this Society, representing as it does the engineering profession in Canada, and including in all classes some seventeen hundred members, is one that carries with it no little distinction, and Dean Galbraith's many friends are exceedingly well pleased that the honor is to be his for the ensuing year Dean Galbraith has been a member of the Canadian Society ever since its charter was granted in 1887, and since 1894 has served almost constantly on its Board of Councillors.

The meetings of the Engineering Society have been uniformly successful. The last general meeting might have been termed a concrete meeting. Two gentlemen representing two entirely different systems were present, and an impromptu debate livened interest in the subject under discussion.

Such a lively interest is being manifested by the undergraduates in the sectional meetings that special sessions have to be arranged to accommodate those who are willing to contribute papers. This is a pleasant change to the old order, when the president had to plead for addresses and discussions.

The fourth year are all working hard to complete their theses. The following is a list of men in the electrical and mechanical department, together with the subjects they have chosen for investigation:

F. G. Allen—The Electric Lamp.

H. D. Bowman—Electric Power Distribution in Machine Shops.

W. S. Brady—Electric Illumination.

C. G. Carmichael—The Standardizing Laboratory.

S. D. Evans—High Tension Transmission.

F. R. Ewart—Switchboards and Their Apparatus.

C. S. Grassett—Electric Power Transmission.

H. O. Hill—Producer Gas for Power.

T. H. Hogg—Design and Construction of Ontario Power Company's Plant.

C. W. Hookway—Electrical Illumination.

A. H. Hull—Factory Testing of Generators and Motors.

C. H. Hutton—Lightning and Lightning Protection Apparatus.

E. W. Hyman—Direct Current Heavy Traction.

L. G. Ireland—Polyphase Induction Motors.

E. W. Kay—Direct Current Armature Design.

A. D. LePan—Management and Economics of Electric Stations.

D. J. McGugan—Protective Apparatus for High Tension Power Transmission.

F. W. McNeill—Individual Motor Drive and Speed Control.

L. R. Miller—Single Phase Railway Work.

G. E. Quance—Hydro-Electric Power Installation.

E. R. Smithrim—Electro-Plating and Electro-Chemical Refining of Nickel.

A. C. Spencer—Internal Combustion Engines.

O. R. Thomson—High Tension Line Construction.

E. D. Tillson—Electrical Distribution (underground work).

A. F. Wilson—Electric Railway Motors.

J. N. Wilson—Power Transformers.

E. M. Wood—The Control of High Potential Systems.

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## WHAT THE GRADUATES ARE DOING

**On this page we shall be pleased to publish *professional* news of any of our graduates.**

It is impossible to keep a good man down. F. W. (Casey) Baldwin, '06, is associated with Professor Graham Bell in his experimental work on air-ships.

J. T. M. (Thrift) Burnside, '99, is pursuing his profession in China.

The stringency in the money market has forced a number of our graduates out of employment. One compensating feature, however, is that they have seized the opportunity of renewing old acquaintances around the University.

E. A. James, B.A.Sc., '04, took over the editorship of the "Canadian Engineer" at the first of the year. If he puts one-half the enterprise and energy in the journal that he put into the Engineering Society, great things may be expected in the future. The "Canadian Engineer" is to be congratulated on securing his services.

W. F. Wright, '04, has been promoted to Chief Engineer, Denver District General Electric Co. His headquarters are Denver, Colorado.

W. S. H. Keefe, '04, is manager of the Fort Covington Light, Heat and Power Co.

F. Grant Marriott is chemist and superintendent of the asphalt plant for city of Toronto.

M. S. Culbert, '02, is manager of the O'Brien mine, Cobalt, Ontario.

R. (Bob) Bryce is manager of the Silver Queen.

Wm. F. Ratz, D.L.S., '02, is on the staff of International Boundary Surveys. For the past three years he has been engaged in the survey of the International Boundary between Canada and Alaska.

Rutherford Cummings, '02, after being associated with

Haney & Miller for some years, has started business for himself as a general contractor. One of his first contracts is the new Ontario Government Experimental Sewage Station.

William G. Chase, '01, is a member of the firm of Smith, Kerry & Chase, Confederation Life Building, Toronto. His firm was consulted in the estimates for municipal power distribution plant for Toronto.

Toronto graduates are playing an important part in the electrical development of the country, including the plants at Niagara, where all the power companies, including the American, have employed school men extensively. The Canadian company, with that loyalty which is characteristic, have employed foreign talent almost exclusively.

Arthur Laidlaw, '01, is a district manager of the Trussed Concrete Steel Co., with headquarters at Kansas City, Mo., and Omaha, Neb.

D. E. Eason, '01, is district engineer, Trent Valley Canal, at Peterboro.

William Hemphill, '00, is general foreman for the Cataract Power & Conduit Co. at Buffalo, N.Y.

W. Almon Hare, '99, is secretary-treasurer and chief engineer, Standard Engineering Co., Toronto.

H. V. Haight, '96, is chief engineer, Canadian Rand Drill Co., Sherbrooke, Quebec.

Gordon M. Campbell, '96, is superintendent Western Electric Co., Chicago.

Harold Rolph, '94, is vice-president, Metcalf Engineering Limited, Montreal.

L. E. Charlesworth, '93, is Director of Surveys, Edmonton, Alberta.

## "YE LADY ENGINEER"

*"Laughter and tears are meant to turn the wheels of the same machinery of sensibility; one is wind-power, and the other water-power; that is all. * * * * The ludicrous has its place in the universe; it is not a human invention, but one of the divine ideas."—Autocrat of the Breakfast Table.*

(Illustrations by W. Van R. Reynolds.)

Dear Sir,—Your communication of the 20th ult., announcing my appointment to a Special Comimttee to report upon the admission of lady members, duly received. As requested, I have carefully noted the information given, as follows:

Item 1. Prof. Starr, of Chicago University, in a very widely reported lecture, declares that women students have a stronger grip on mathematics than the men, and that the men are more emotional than the women.

Item 2. The "Technical World," October, 1906, announces that Miss Nora Stanton Blatch has been elected to membership in the American Society of Civil Engineers; also that

Item 3. The University of Colorado has recently graduated its first woman engineer.

Item 4. A late "Engineering News" records the fact of Miss Elsie Bittman having vacated a $1,200 draughting position in the New York City Bureau of Highways for an assistant engineership on subway construction.

Now, Mr. Editor, if you will allow me a few lines in which to air my views upon the foregoing, you will partially excuse, I hope, my slowness in deciding to act on this Special Committee.

The facts set forth in your letter presumably are intended to convince me that the old order is changing, and that it devolves upon the Applied Science to act in recognition thereof. There certainly does seem to confront us some necessity for alteration in the scheme of things entire—nowadays when we can sit at home and listen to Patti and Melba sing vulcanized rubber songs merely by twisting a crank. But, if it comes to that, where are the copper buns of yesteryear; whither vanished the old-fashioned, particolored sugar stick of tooth-irrigating memory? The stage and the old grey mare going out, and the railway and motor car coming in, means, as someone says, that we arrive at places now, we travel no more. Our pet theories, too, are exploding one by one—deny it we cannot. Modern research is seeking to impugn the rosy cheeks of Newton's apple; to repeal the very laws of gravitation, despite the evidence obtained by the centre of gravity of our waistcoats in a Trader's Bank elevator. Waterfalls, we have discovered, have other uses than to form picturesque pickerel pools; they who seek them out at present writing are promoters and their engineers, and have other fish to fry. But what of the matter more particularly in hand? It seems, then, that in the land to the south they are rushing it to the limit—this *Age* which answers to the equation of—

Criss-cross + catacorner = F + topsy-turvey + higgledy-piggledy; F being a constant representing the date, last past, when the moon was at the full.

In other words, a dimpled trio of comeliness—after publishing the banns for four academic years and a post-graduate course—has become wedded to the engineering profession, following the example of others of the fair sex, who, in other lines, have been united in the holy bonds of making money. They have gone Dr. Mary Walker one better; such appears to be the case.

For my part, wondrous had it seemed had some giddy young damsel in fluffy bangs, beholding lady doctors and lady lawyers and lady such-and-such—every one prospering—not grown clamorous, not longed to conquer the realms of practical scientific intellectuality; to take things out, as it were, to the "henth" power; not yearned to be a mining expert, for example, to go romping after rugged rocks with dinky, diminutive hammer, or to practice civil ingenuity, perchance to prod into the vital statistics of sewers and pavements and septic tanks and so forth, and do telescopic stunts for a microscopic salary, while figuring on the *dramatis personæ*" of a Government survey, just like many of the lords of creation. I could have told you so. Satan finds some mischief still for the hand that rocks the cradle.

This Chatauqua business was bound to be overdone. Airy, fairy Lillian, once she cultivated a bowing acquaintance with long-legged words ending in *-osity* and *-ism,* would be sure to pursue the downward path, and ere long stumble against an introduction to specific gravity and voltage and such like. When she commenced seeking the mother-lode of erudition, from acquiring the Latin word for a water-beetle—don't you know—to reading periodicals infested with higher mathematics, and cultivating a craving for strength of materials and conic sections, the gradient is remarkably easy. The seed had been scattered, the soil was fruitful, one had but to squat on a roadside stump and take an observation of the harvest.

While still in frocks that flirted with their boot-tops, they had read their Tennyson—these saucy, winsome lassies—probably knew him all by rote, most of them, and in a desire to throw off the "sooty yoke of kitchen vassalage" can you marvel that a few gathered up their skirts and jumped the fence into the engineering field? Was there any reason why they could not take 2 and 2, and multiply them together, and dally just as learnedly as the men with the finished product. Nay, nay, Pauline. Not by a back sight!

So, from her mother's kitchen my lady charming passed to the school of technology and the laboratory thereof—gathering lore ament the intricate fusing of metals, eating of the tree of knowledge of the *entente cordiale* between Sodium and Magnesium, and getting wise to the proposition that Cobaltite and Nicolite moved in the same set.

It was only the merest step from the rolling pin to the parallel-ruler; from being a dab at domestic functions to proficiency in functions algebraic—the slitheriest sort of lubricated transition; from being chief push at a Domestic Science meeting to reading a paper on some such subject as "Reinforced Cow-meat" was like sliding off a log. Fish-plates and fashion-plates are confusing in shorthand. Beet roots and cube roots nearly are allied.

Looking abroad, then, and rolling a melting eye, and rubbing shoulders with successful female barbers and dentists, it was nothing but natural for some ambitious Alice, or Priscilla, or Phyllis, or Eunice, to hazard a bet in an idle moment that she would yet reach the head of engineering navigation, and snug fast in one tender, loving hug of exceeding largeness, to the fat salary that environs the crafts and subtleties of the consulting engineer.

The men have only themselves to blame, perhaps. Here, for years they have been practising deceit. The ladies were sure to find out after a time that a dam is not merely a long, low, splashy-looking thing with green moss and poetry and stuff on it, where the boys have their swimming hole; but also that good money may be made at home by figuring and making plans about it before it is built and flops over. Nobody likes being gammoned, and that's why the gentle, adorable Doris is elbowing the men and stooping to the profession—why woman, lovely woman, is bringing herself down to a mere man's level, and transit.

There is no use telling the dear creatures, these sweet and radiant handmaidens of Science, what they are up against, I suppose. If they knew the tariff charges, unless I miss my guess, it would be a kissing game of good-bye to the civil enginine. However, as the profession claims as many different varieties as Heinz's pickles, it may be assumed that there's a lot of gentle-eyed gazelles perched on the verandah and watching to see if this first bunch of beauty makes good before taking the plunge. If one brand doesn't seem appetising, there's a lot of others left. That's doubtless what they think. Ruth crushed to earth will rise again. But, being kind-hearted, I sadden, I hasten to drop the unfeigned tear! Could a thought more hateful than leaving them to fry in their own fat be imagined?

I suppose the whole crusade started with that disinherited tradition about the Transit of Venus, and how Venus laid out the Milky Way, and the further discredited idea that she gave her arm to make the third leg of the tripod. Or have they gone crazy from playing bridge?

Mercy me, what wielding of logarithms with the energy that should flow in full, free, fast flood, undefiled, toward the carpet sweeper! What cluttering of feminine brains with labyrinthine formulæ! What acquisition of wrinkles over Chambers' Tables when the time were better employed in ironing wrinkles out over the tables in the laundry, must ensue, ere these poor, deluded but beautiful blossoms of loveliness realize their mistake, acknowledge that it is better far to know how to scale a nice fresh herring than a plan—not to say, bake a tapioca custard than cook field-notes.

After all, my dear Mr. Editor, the point I make is, that what has come to pass is not in our own country. The germ has been isolated and propagated, let us admit, more or less successfully under the Eagle's wing; but it is all experimental, and from Uncle Sam's domain to ours is a far fly. Upon mature deliberation I consider Applied Science unduly excited and tanbarking up the wrong tree. I grant, of course, the advent of a new era, and that Canada is going to loom large; that "with enormous untouched natural resources," etc., already has she begun to bring her pigs to market—and billets, too—and that no longer will we sit down and say grace over bare bones. All of which signifies that the day of the engineer and surveyor is here.

It is true that many young ladies have come from Toronto University with the centre B and distance B.A. in their bonnets—have done so for years—but reading Moderns, and Kant, and messing round the fourth dimention and such like, is different to having technical and mechanical fal-da-rals seething in your brain-pan. If a fellow like me, who is trying to get three squares a day out of engineering, may be permitted to have such grave, mighty thoughts locking through his cogitatory canal, I should say that our maidens can be *tete-a-tete* with Macaulay and Gibbon without interfering with the artistic *tout ensemble* of the stuffed canaries on their Sunday morning hats; yet that these same sweet lady graduates are too sensible to fail to understand how the paths of survey lead but to grey hairs; how working fakes with a lathe, or frivoling with bridge construction or twisting on or off the juice in a power house, are things better left to brother Tom. We bring our daughters up better. We do

not want to be reading advertisements of "Maiden Canada" engineers.

There is the eternal fitness of things to be considered, despite the fillip given to some minds by the quaint, the unexpected. "A Madonna of the Sand Pump" would not look right. Resolved, that a horn spoon is the best for the mustard pot; also that ginger beer tastes better from a stone bottle, whilst the ordinary hayfield variety of beer—accepting the knowledgeable dictum of the immortal Bob Sawyer—yields its ultimate strength, imparts its most delicious, nut-brown quintnnessences to the wetted perimeter known as the right spot, only from "it native pewter." Nay, a plumb-bob would not feel at home waggling at the end of a corset string. It is all very well for the "Technical World" man to get busy and make statistics for printers' copy. But stop for a moment and consider the absurdities of it all!

Picture your draughting office! A dainty, demure, tender dove of a damsel over there in the corner, with a prodigal wealth of auburn tresses her head adorning, and a truncated cone of ditto behind—impressionable, she, as a fresh-trowelled concrete walk—just fancy her, intent plotting curves for permeability and calibration or efficiency and power factor, or some other thing, and lining her snow-white, patrician brow till it resembles a terminal yard; the fair, pure oval of her face tuck-pointed from chewing gum; with it all an intangible yet prevading aroma of lavender or new-mown hay in the air! Is't not a presentment to set you a-dreaming of lyrics and sonnets and strophes! "And they called her Maud." The drawing room! "Imagination fondly stoops to trace the parlor splendors of that festive place," as per the poet. What ashape your papers would get into—estimates jabbed together with safety pins and what not. Under the regime of one's able assistant, Miss Fluffy Ruffles, Spinster of Applied Science, would not one's reports and specifications have more postscripts than a steel tape gets kinks? Just think, think—let your fancy have play—the walls! Bunches of celluloid set squares and French curves tied up with baby ribbon. My very soul is harrowed. What insertion in the drawing paper, what tucks taken in the cross-sections, what three-inch pleats in hemstitched profiles, would signalize the invasion of sighing Jean, or cooing Dolly, in her Peep-a-view shirt waist, and side-stepping hither and thither, flaunting, fluttering—with a mouthful of drawing pins! 'Ods precious; only conjure up the stuff you would always be finding on your best embossed letter-paper after she had gone for the evening, an' it please you. She

would set up her muse, and level it, and run "Lines to a Gravel Pit" after some such fashion as:

> "Oh, to be carted away
> From this dark Aceldama of sorrow,
> Where the gravel and sand of to-day
> Becomes the concrete cub. yd. of to-morrow."

Would you like that? Would it be seemly? I grant that plenty of our draughtsmen lack the brains of a horse on a milk route, and that now and again one might count on an artistically-minded female who could manage a plan which when completed didn't look as though its necktie were up over its collar, but—my word for it—the lady draughtsman is yet a long way off. Do you think they would ever date a drawing? No, the betting is 20 to 1 against pink T-squares. There are too many other congenial occupations—if they will not stay at home and help mother, and recreate with *Trolley-era Rusty-piano* sort of music when Mr. Smithkins calls of an evening—too many vocations for them to confess to any wistfulness for a bridge, or languishment for a five-mile breakwater, or love for a septic tank, or desire for a bevy of culverts. And if the Engineering Society is serious it surely must be holding the telescope to its bad eye.

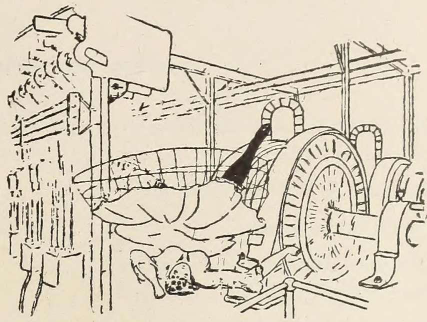
Their common sense will teach the ladies that digging ditches and cumbering the earth with viaducts are not for the likes of them. Our Lady of the Snows (be the last same, more or less) has no hankering to go roaming up and down creation jabbering about test-tubes, and assays, and load-factors, and shaft-sinking, *et al,* like a lather with a mouthful of nails. They recognize that a pretty girl and plane trigonometry—be the moon ever so lovely—are incompatible, incongruous.

Why, the idea is so silly! First thing, we'd be having "Rules of Professional Etiquette on Sewer Work," and a new column in the "Ladies' Home Journal," headed "Complexion Aids for the Field." The longer I ponder the whole proposition, the more decided I become.

Hark! list!—do you hear the pathetic, undertone query, "Is my instrument on straight?" Ludicrous, crazy, the entire hypothesis!

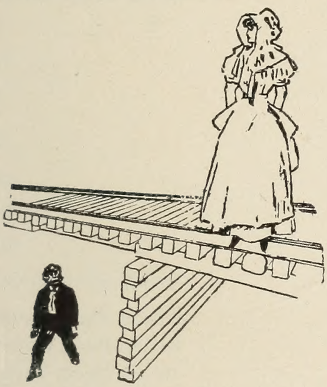
Behold Gladys Edythe—tricksome goddess, serenely sweet—wrestling on a cold, windy day with the thumbscrews, in a pair of No. 6 suede gloves, the whiles her dainty tailor-made gown plays clothes-line with the tripod. Gaze on her trying to negotiate the elusive cross-hairs, what time her feather is frisking between the bubbles like the swipe of a Newfoundland dog's tail. . . . I believe that there are a lot of other girls who affect squashy, deep-apple-pie kinds of headgear, with a chop suey adjunct of violets, or assorted fruits, or something clinging to the soffit of its *porte cochere;* but if we can imagine a lady surveyor or engineer at all,

in either case—if she were giving line and god mad and tore it off and threw it down and jumped on it—the resultant would be the same by the graphical method.



Suppose crinolene to come in, and Alicia in a power plant! She'd go fooling about—blonde curls, cunning curls—get caught in the shafting or make a short skirtlet, and just then things would be hooping up generally.

Think of her measuring on a trestle, with notebooks and powder puff, and tape and pencils, and red chalk and smelling salts, and the usual incidentals in her chatelaine. She'd be yelling in a rich deep mezzo-soprano to Kelly, the foreman, to yank those ties off quick, or get to the calorific equivalent out of that. Would Kelly, think you—whose language, when he is caught without an umbrella in a brainstorm, is often so bad that his mouth needs a mud-guard—be apt to study fastidiousness in his repartee to those pearly cadences issuing from those ruby lips? Deponent sayeth not, nor yet putteth it in writing.



The foregoing, my dear Mr. Editor, are but the more obvious things that occur to me. I am not going into delicacies. But love my heart alive, would not every survey demand a chaperone? Ye gods, what a vision!

No, doubloons to ditch-water, 'twill be a long, long day ere the saying changes to "Oh, for blue prints like my mother used to make." The civil enginine's contract is too much inclined to *embonpoint,* and we need fear no foe in the guise of a moth-ball rolling care-free in the tracing-cloth drawer. Winging to covert in the technical section of the "Idle Rich" is a grown man's job.

And all of the above, Mr. Editor, makes me opine that the Engineering Society need not let worry sit too heavy on its chest. After reading same, if you still think the Committee necessary, and that it's up to me to act, you have only to say the word.

With best wishes, believe me,

Yours truly,

E. C. Easy, C.E.

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